**WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care**

**Worksheet author(s)**

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### Clinical question.

Question (Peds-041A) “In children and infants with cardiac arrest from major blunt of penetrating injury (out of hospital or in hospital) (P), does the use of any specific modifications to standard resuscitation (I) compared to standard resuscitation (C), improve outcome (O) (eg. ROSC, survival)? eg. open vs. closed chest CPR, other examples”

**Is this question addressing an intervention/therapy, prognosis or diagnosis?**  
Intervention/therapy

**State if this is a proposed new topic or revision of existing worksheet:**  
Ne topic

### Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No

### Search strategy (including electronic databases searched).

- Pub Med: “traumatic arrest” as MESH heading with “resuscitation” as text word in abstract.
- Pub Med: “cardiac arrest” as MESH heading with “traumatic” as text word in abstract.
- Pub Med: “traumatic arrest” as MESH heading with “pediatric” as text word in abstract.
- Pub Med: “pediatric” as MESH heading with “resuscitation” and “trauma” as text words in abstract.
- Pub Med: “resuscitative thoracotomy” as MESH heading with “pediatric” as text word abstract.
- Pub Med: “penetrating chest injuries” as the MESH heading with “pediatric” as the text word in the abstract.
- Pub Med: “blunt chest trauma” as the MESH heading with “pediatric” as the text word the abstract.
- Cochrane review: “pediatric traumatic cardiac arrest”
- Cochrane review: “traumatic cardiac arrest”
- Cochrane review: “emergency intubation”
- Google scholars: “traumatic cardiac arrest”
- Google scholars: “pediatric traumatic cardiac arrest”

### State inclusion and exclusion criteria

**Inclusion criteria:**
- Pediatric traumatic cardiac arrest
- Traumatic cardiac arrest
- Penetrating chest trauma (adult and pediatric)
- Bunt chest trauma (adult and pediatric)
- Resuscitation from traumatic arrest
- Resuscitative thoracotomy

**Exclusion criteria**
- Drowning
- Electrocution
- Lightning strike
- Hanging

### Number of articles/sources meeting criteria for further review:

42 articles. Of these three were LOE-3, nine were LOE-4, and twenty-seven were LOE-5. Three were review articles.
# Summary of evidence

## Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
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### Level of evidence

- **A** = Return of spontaneous circulation
- **B** = Survival of event
- **C** = Survival to hospital discharge
- **D** = Intact neurological survival
- **E** = Other endpoint

**Italics = Animal studies**
### Evidence Neutral to Clinical question

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<th>Level of Evidence</th>
<th>Evidence Neutral to Clinical question</th>
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<tr>
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<td>Hutchison 2008 CDE</td>
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<td>Lecky F 2008 CD</td>
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<td>Ehrlich 2004 E</td>
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<td>Morris 2004 C</td>
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<td>Pickens 2005 BCD</td>
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<td>Sirbaugh 1999 BCD</td>
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<td>Corral, 2007 ACD</td>
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<td>David 2007 ACD</td>
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<td>Di Bartolomeo 2005 EBC</td>
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<td>Deakin, 2008 ACD</td>
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<td>Hall 2004 E</td>
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<td>O’Brien 2008</td>
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<td>Takino 1993 ABCD</td>
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<td>Willis 2008 ABCD</td>
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**Level of evidence**

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### Evidence Opposing Clinical Question

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<td>Cera 2003 BC</td>
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<td>Stockinger 2004 CD</td>
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**Level of evidence**

- A = Return of spontaneous circulation
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- E = Other endpoint

*Italicics = Animal studies*
Cardiopulmonary arrest from trauma is associated with dismal outcomes for children and adults. Rates of survival to discharge are under 10%, and survival without neurological sequelae are less than 5% (Hazinski, Lopez-Herce 2004, Fisher 1999, Sheik 1994, Suominen 1998, Bennet 2008, Huber-Wagner 2007, David 2007). Guidelines for withholding and terminating resuscitation in prehospital traumatic cardiopulmonary arrest have been put forth for adults by the American College of Surgeons and the European Council On Resuscitation (Hopson 2004, Soar 2005). These organizations have recommended withholding CPR in the field if the patient is apneic, pulseless, lacks any organized cardiac rhythm or signs of life; and consideration of termination of resuscitation should be given for patients with witnessed cardiac arrest without ROSC after 15 minutes of CPR. Several authors have reported survival of adult patients outside of these recommendations (Pickens 2005, David 2007, Powell 2004, Huber-Wagner 2007).

Despite reasonably well-accepted parameters for withholding resuscitation or terminating resuscitation in adults with traumatic cardiac arrest (Stockinger 2004), no such criteria exist for children. The presence of an organized cardiac rhythm, lack of a pulse or signs of life have not proven to be predictors for failure to attain ROSC or sustained ROSC in children (Lopez-Herce 2004, Lin 2007, Crewdson 2007). Additionally, prehospital EMS crews are less likely to follow recommendations of withholding resuscitation in children with traumatic cardiac arrest than for adults (Hall 2004, O’Brien 2008). This has led to children receiving prehospital and in-hospital resuscitation for traumatic arrest. Standard resuscitation would be considered BLS in the field and ACLS/PALS in the hospital. Data from Lopez-Herce 2006 and Lin 2007 suggest that children with traumatic cardiopulmonary arrest should have at least 20 minutes of in-hospital CPR performed. Failure to obtain ROSC after 20 minutes of CPR was associated with no survival in both of these studies.

The question this worksheet attempts to evaluate is are there any adjuncts to standard resuscitation for cardiac arrest from blunt or penetrating trauma that lead to improved outcomes as measured by ROSC, sustained ROSC, and survival to discharge. Adjuncts to standard resuscitation that have been evaluated in this worksheet include resuscitative thoracotomy (in the field and in the hospital), prehospital care by advanced capability (physician or emergency nurse) led teams, hypothermia and hypothermic preservation, and extracorporeal life support (ECMO).

Resuscitative thoracotomy and internal cardiac massage:
The role of resuscitative thoracotomy in the treatment of pediatric traumatic cardiopulmonary arrest remains difficult to define. Meaningful survival following emergency department thoracotomy for traumatic arrest for blunt trauma in adults and children is rare (0-2%; Sheik 1994, Fisher 1999, Powell 1988, Rothenberg 1989, Beaver 1987, Suominen 1998, Bennett 2008). Resuscitative thoracotomy for cardiac arrest from penetrating trauma has better outcomes with survival rates reported from 1-36% in select patients (Cothren 2006, Powell 1988, Powell 2004, Lo 2007, Seamon 2008). General indications for resuscitative thoracotomy in adults include: in blunt trauma arrival to a hospital with vital signs followed by a witnessed loss of vital signs; penetrating trauma victims with suspected thoracic injuries with vital signs in the field who have a witnessed loss of vital signs; victims of penetrating injuries with cardiac arrest from abdominal or major vascular injuries (Hopson 2004, Soars 2005). The case series used to develop the recommendations for adult resuscitative thoracotomy often included a small number of children. There are five pediatric specific series (Powell 1988, Rothenberg 1988, Beaver 1987, Suominen 1999, Sheik 1994) have evaluated resuscitative thoracotomy in patients under 19 years of age. Sheik 1994 and Suominen1999 found no differences in ROSC and survival in children cardiac massage compared to closed chest massage. Powell 1988 reported a 36% survival rate following resuscitative thoracotomy done for penetrating trauma and 12.5% for blunt trauma in 16-18 year olds; but there were no survivors under age 15. Beaver 1987 had no survivors children who had a resuscitative thoracotomy. Rothenberg 1989 reported a 5.6% survival following resuscitative thoracotomy for penetrating injuries and 2% survival for blunt injuries in patients under 19 years of age. In aggregate, these five series report on a total of 8 survivors following 139 resuscitative thoracotomies (5.8% survival). Calkins 2002 did note a 13% organ donor rate in children who had ROSC after CPR but progressed to brain death (thoracotomy not mentioned).

There are individual case reports and several small series of adult patients with cardiac arrest from trauma (usually chest stab wounds) that were successfully resuscitated using an on-scene thoracotomy performed by a member of a helicopter based advanced life support team (usually a physician; Coats 2001, Corral 2007, Deakin 2007). There are no data concerning the use of on-scene resuscitative thoracotomy in children in traumatic cardiopulmonary arrest.

Helicopter advanced capability teams:
Comparisons of helicopter based advanced capability teams (led by an emergency physician, surgeon or emergency nurse) to standard ground ambulance crews staffed by paramedics showed improvements in ROSC in children and
adults but with minimal survival advantages (Crewdson 2007, Di Bartolomeo 2004). Both authors note that emergency chest decompression (thoracostomy) was more likely to be done by the helicopter based teams and that did lead to several survivors. Both of these studies were done in densely populated large European cities. The use of helicopter based physician led resuscitation teams would be a major paradigm shift for North American EMS systems and would not be practical for rural areas.

ECLS
Extracorporeal life support is used on a limited basis for managing posttraumatic respiratory failure. Its use in acutely injured patients is limited and often impractical due to contraindications to systemic anticoagulation (Bennett 2008).

Hypothermia:
Hypothermia is used as a neuroprotective modality in the management of children following medical cardiac arrest and has been applied to patients with traumatic brain injury (Hutchison 2008). There is insufficient data on the use of hypothermia in children with traumatic cardiopulmonary arrest. Large animal and rodent models of controlled exsanguination followed by hypothermic preservation show that these animals may be maintained in "suspended animation" for up to one hour and then rewarmed without neurologic sequelae (Alam 2008:912, Drabek 2007, Nozari 2004).

Prehospital intubation:
The role of prehospital intubation as a part of resuscitation remains unclear but does not appear to impart any survival advantage of bag mask ventilation (BMV). Gausche showed no improvement in survival or neurological outcome in children with traumatic cardiac arrest randomized to in-field intubation versus BMV performed by paramedics in a mature U.S. suburban trauma system. Erlich found that in a rural trauma setting that in-field intubation appeared to be associated with more complications and no survival advantage over BMV (Erlich 2004). A Cochrane review found no data to support in-field intubation in pediatric trauma patients (Lechy 2008).

Acknowledgements:

Citation List


LOE 5: Fair. Supports clinical question. Animal study using of traumatic hemorrhage using profound hypothermia to induce a state of suspended animation. Animals exposed to less than 60 minutes of profound hypothermia survived neurologically intact. If this work can ever be extended to humans it has great potential for ultimately being able to place injured patients into suspended animation in the field and then repair injuries prior to reanimation.


LOE 4: Fair. Opposes clinical question. Retrospective study from one center. No survivors in a group of pediatric trauma patients who appeared to initially be salvageable who underwent ED thoracotomy.

LOE: 5 Fair. Review article of the outcomes of adult and pediatric traumatic arrests.
Note: This article was used for background information and is not listed in the evidence grid.


LOE 4, Fair. Neutral. Is a retrospective analysis on a Regional Pediatric Trauma Center. Authors studied only 25 children with cardiac arrest after blunt trauma and only two survived. Both had no head injury, had vitals in the field, and CPR was administered initially in the emergency department. 13% of children with RoSC went on to become organ donors.


LOE 5: Poor. Opposes clinical question. Retrospective review of adult patients with post-traumatic cardiac arrest. Survival was poor; pupillary response and sinus rhythm upon resuscitation were predictors of survival.


LOE 5 Poor. Supports clinical question (but very limited study). Retrospective review of adult patients undergoing prehospital thoracotomy for traumatic cardiac arrest from penetrating trauma performed by a helicopter based emergency response team. Overall survival was poor, but in selected situations was of some utility and resulted in 10% survival (90% neurologically intact). Patients with a primary respiratory cause of arrest (tension pneumothorax) had the best survival.


LOE:5. Poor. Neutral. Case report of a successful in-field resuscitative thoracotomy done for trauma by an advanced response team. Not applicable in most EMS systems. Not enough evidence to support advocating this approach in adults do to limited sample size.


LOE: 5 Fair. Review article of the outcomes of adult and pediatric traumatic arrests.
Note: This article was used for background information and is not listed in the evidence grid.


LOE 4, Fair. Support. This is a ten-year retrospective study on a trauma database. 80 children with pre-hospital traumatic cardiac arrest were studied. The survival to hospital discharge was 8.7%.


LOE 5 Poor. Neutral. Adult study of cardiac arrest from trauma vs. medical conditions. Nearly all trauma was blunt. No differences found in rates of ROSC, discharge and neurological recovery between traumatic and medical arrests (results better than expected for both groups).


LOE 5; Poor. Neutral. Adult patient prospective study comparing helicopter based ALS transport systems versus basic life transport systems for patients with traumatic cardiac arrest. The ALS transport group had more opportunity to resuscitate patients but no survival advantage was found over basic life support transport.


LOE 5; Fair. Support clinical question. Animal study of hypothermic exsanguination-perfusion. Survival with 60 minutes of EPR but no survival at 75 minutes.


LOE 5. Fair. Neutral. This is a ten-year retrospective study in a paediatric trauma centre. Moreover this study has very important limitations. 106 endotracheal intubations attempts performed by paramedics, flight nurse or physicians were analyzed. Only 6.5 % of these attempts were in patients with cardiac arrest and 4.5 % in respiratory arrest. and it did not analyze separately.


LOE 5 Poor. Oppose. Retrospective review of children having cardiac arrest from blunt trauma in San Diego County. Poor survival (1 out of 65), but organ donation noted in moderate number of patients.


LOE 5. Good. Neutral. This is prospective controlled study performed on 820 children who required out-of-hospital respiratory assistance. The main results of this study is not there were no differences in survival or neurological outcome when bag-valve-mask ventilation and endotracheal intubation is performed by paramedics. The main limitations were that trauma and non-traumatic causes, and cardiac or respiratory arrest and other causes for respiratory assistance were not analyzed separately.


LOE 5: Poor. Neutral Study evaluating paramedics attitude about termination of resuscitation for pediatric patients with out of hospital cardiac arrest.

LOE 4; Good. Oppose. Prospective series of children with cardiac arrest from blunt trauma treated at a level I trauma center. One patient survived, but had profound neurological damage. Organ donation rates high in children who had ROSC.


LOE:5 Guidelines based on literature review. 
Note: This article was used for background information and is not listed in the evidence grid.


LOE5: Fair. Support. Is a retrospective analysis in a prospective trauma registry in adults. The main result was that insertion of a chest tube on-scene was a factor significantly increasing the probability of survival, and that recognition of patients with tension pneumothorax and early intervention increased survival. The survival of patients without an easily reversible cause for traumatic arrest (e.g. tension pneumothorax) had extremely poor outcomes.


LOE 3: Good. Neutral Prospective, randomized trial of children randomized to hypothermia vs. normothermia following cardiac arrest. No improvement in survival with hypothermia.


LOE5. Good. Neutral. This good Cochrane revision that analyzed the emergency intubation in randomized or controlled clinical trials in traumatic and non-traumatic adults and children. However only 3 studies were found (2 in nontraumatic adults and 1 (Gausche article in children). For this reason there are no data to perform a recommendation


LOE 4 Good. Support. Retrospective review of children with cardiac arrest comparing those with traumatic arrest to a cohort with cardiac arrest form nontraumatic causes. Trauma patients had worse outcomes than nontrauma patients.


LOE: 5 Fair. Opposes. This paper is a primarily an adult series of trauma patients who presented to the ED without a pulse or respirations. 9 of 144 survived for 24 hours but none survived to discharge. Due to the cardiopulmonary arrest.


LOE 4. Good. Support. It is a secondary analysis from a prospective multicenter study of cardiac arrest in children. The main limitation of this study is that only 28 children with traumatic cardiac arrest were studied. The main prognostic factors were respiratory arrest when resuscitation is started and duration of resuscitation less than 20 minutes.


LOE 5; Fair. Neutral. Retrospective review of children placed on ECMO after in-hospital cardiac arrest of mixed etiologies. Poor survival, but children with cardiac disease had best survival. Very few injured patients in this series.


LOE 5; Fair. Support. Suspended animation induced by profound hypothermia following exsanguination in a canine model. Survival can be seen following 60 minutes of cardiac arrest.


LOE:5. Poor. Neutral. Study that looked at impact of termination-of-resuscitation protocols for trauma on an EMS system. Very protocol violations occurred, none of the patients who met termination-of-resuscitation criteria but were transported to an ED in violation of protocol survived.


LOE 5; Fair. Patients getting field CPR showed better outcomes if they had any of the following: pulse in field of ED, GCS>3. pupil response, any ECG activity, any motor activity all associated with increased outcome independent of age, gender, mechanism of injury. Ages 2-87yrs but data on pediatric patients not specifically given (adult study as best as can be determined since age breakdown not given). All survivors older than 16 yrs.


LOE: 5 Fair. Neutral. Adult series from large U.S. Level 1 trauma center. Authors found Emergency Department resuscitative thoracotomy to be futile in blunt trauma patients requiring prehospital CPR for more than 5 minutes and penetrating trauma patients requiring prehospital CPR for more than 15 minutes. This study reinforces that patient’s with traumatic cardiac arrest from blunt trauma have dismal outcomes, but patient’s with TCA from penetrating injuries had a surprisingly good rates of survival and good neurological outcome if they required less than 15 minutes of CPR prior to EDT.


LOE: 4 Fair. Support. Review of patients who had an ED thoracotomy performed; all were considered moribund on arrival. The authors conclude that resuscitative thoracotomy is efficacious in patients with penetrating trauma (36% survival). The drawback of this study is that no patients in the 0-15 age group (5 penetrating, 4 blunt) survived (all survivors age 16-18). Does not appear to support resuscitative thoracotomy for blunt cardiac arrest
(1/8 survivors).


LOE 4, FAIR. Neutral. This study was an analysis of patients age less than 19 years of age who had an ED thoracotomy performed at a large, urban level I trauma center over 11 years. There were 83 patients age under 19 out of 689 consecutive ED thoracotomies. Despite survival rates of 9% for stab wounds, 4% for gunshot wounds, and 2% for blunt trauma the authors advocate the use of ED thoracotomy for patients less than age 19 who have penetrating injuries irrespective of prehospital physiological status, and for blunt patients arriving lifeless in the ED. Given their data, the author’s recommendations seem to be somewhat ambitious and feel this study study is neutral to whether resuscitative thoracotomy is of any benefit for blunt trauma (no from this data) and penetrating trauma (minimal to no benefit) at best.


LOE 5: FAIR. Support. This paper is a retrospective review from an urban level trauma center looking at 180 EDTs performed for penetrating injuries between 2000-5 90% were gunshot wounds (GSW) and 10% stab wounds (SW). All patients were 16 years or older. Outcomes were survival to the OR, survival at 48 hours, and survival to discharge. 52 (28.9%) survived EDT to OR. 13 (13.3%) survived 48 hrs. 12 (12.8%) survived to discharge. All survivors were neurologically intact. Predictors of survival were signs of life (SOL) in the field (95.7% of survivors), SOL in the ED (87%), sustainable cardiac rhythm (65%). Of note all patients originated within two miles (3.2km) of the trauma center (Temple University, Phila, PA) and mean EMS transport was 19 minutes. Nonsurvivors were more likely to arrive in ED asystolic or with PEA.

What's new in this study?
1. Anatomic location of injuries did not influence survival (i.e. cardiac, chest, abdominal or exsanguinating extremity injuries were all indications for EDT and no particular location did better); type II error
2. One patient did not have any SOLs and was asystolic in the field and survived neurologically intact (falls outside COT guidelines for EDT, JACS 196:475, 2003).


LOE 2: Fair. Oppose. Pediatric open cardiac massage vs closed massage.


LOE:5 Guidelines based on literature review.
Note: This article was used for background information and is not listed in the evidence grid.

LOE 5. Poor. Opposes. This is a retrospective study in 588 adults patients with trauma who received cardiopulmonary resuscitation. The study confirms the low survival of traumatic cardiac arrest.


LOE: 4. Fair. Support. Pediatric series of trauma patients who received CPR (and resuscitative thoracotomy in some cases); outcome poor but best in patients who suffered cardiac arrest secondary to respiratory arrest.


LOE: 5 Poor. Neutral. Adult patients who had a resuscitative thoracotomy for non-traumatic out-of-hospital cardiac arrest were compared to a similar group of patients who had closed chest were evaluated for ROSC. Univerally poor outcomes were seen.


LOE 5: Poor. Neutral. Adult series of trauma patients who received prehospital CPR. Survival poor for blunt and penetrating trauma. Patients who had possible hypoxic or electrical causes for cardiac arrest (in addition to trauma) had better survival than patients with purely hemorrhagic causes of cardiac arrest.


LOE:4 Fair. Neutral. Prospective study of out-of-hospital pediatric cardiopulmonary arrest. A small subset of patients sustained traumatic cardiopulmonary. Patients with a respiratory etiology of their arrest had best outcomes. Trauma patients with a primary respiratory etiology for cardiac arrest had better outcomes than those with hemorrhage as a source of arrest.