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

Worksheet author(s)
Robert Michael Sutton MD
David Zideman MD

Date Submitted for review: August 13, 2009

Clinical question.
In infants and children in cardiac arrest (out-of-hospital and in-hospital) (P), does any specific compression depth (I) as opposed to standard care (i.e., depth specified in treatment algorithm) (C), improve outcome (O) (e.g., blood pressure, ROSC, survival)?

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

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

Conflict of interest specific to this question
Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? Robert Michael Sutton MD has a scientific interest in this area of resuscitation research.

Search strategy (including electronic databases searched).

- **ECC Endnote Master Library March 24 2008**
  Query: “depth”[All Fields] AND "cardiopulmonary resuscitation"[All Fields] AND "children"[All Fields] OR “depth”[All Fields] AND "cardiopulmonary resuscitation"[All Fields] AND "infant"[All Fields]: **1 hit**

  Query: depth[All Fields] AND (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields])) OR "cardiopulmonary resuscitation"[All Fields]) OR "compression"[All Fields]) AND "infants"[All Fields]: **9 hits**
  
  Query: depth[All Fields] AND (("cardiopulmonary resuscitation"[MeSH Terms] OR ("cardiopulmonary"[All Fields] AND "resuscitation"[All Fields])) OR "compression"[All Fields]) AND "children"[All Fields]: **22 hits**

- **Cochrane Library (issue 3 - 2009) in all Cochrane Databases**
  Query: “depth”[All Fields] AND "cardiopulmonary resuscitation"[All Fields]: **33 hits**

- **Embase (1966-2009)**

Excluding duplicates, the overall search of PubMed, Cochrane, Embase, and ECC Master Library yields: **33 hits**.

- **State inclusion and exclusion criteria**

  Searches were limited to articles in peer-reviewed journals between the years 1966 and July 2009 and no abstracts were included.

  **Inclusion:** human, adult studies, surrogate (manikin), animal and mathematical models
  
  **Exclusion:** studies with children as CPR provider, compression depth not intervention of interest, or review articles

- **Number of articles/sources meeting criteria for further review:** **6**
  
  - resulted in **13** additional studies pulled by review of study references, forward search using SCOPUS
## Summary of evidence

### Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Bellamy et al. 1984(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Kern et al. 1986(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Bircher et al. 1985(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Edelson et al. 2006(A)</em></td>
</tr>
<tr>
<td></td>
<td><em>Kramer Johansen et al. 2006(A)</em></td>
</tr>
<tr>
<td></td>
<td><em>Ornato et al. 1989(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Babbs et al. 1983(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Wik et al. 1996(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Dean et al. 1987(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Kern et al. 1988(E)</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fair</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Kao et al. 2009(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Braga et al. 2009(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Sutton(b) et al. 2009(E)</em></td>
</tr>
<tr>
<td></td>
<td><em>Pickard et al. 2006(E)</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Poor</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Good</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Maguire et al. 2006(E)</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fair</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Poor</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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 Opposing Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fair</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>Maher et.al. 2009(E)</td>
<td></td>
</tr>
</tbody>
</table>

Level of evidence

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

REVIEWER’S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

Current guidelines recommend compressing the pediatric / infant chest during CPR approximately 1/3 to 1/2 the AP diameter of the chest, a recommendation based primarily upon expert opinion. In animal models and adult CPR investigations, there is data to suggest that deeper chest compressions are more effective to improve arterial blood pressure / perfusion pressures [Bircher, 1985; Kern, 1986; Ornato, 1989; Bellamy 1984] or short term outcomes [Kern, 1988; Kramer-Johansen, 2006; Edelson, 2006], however, no prospective pediatric study has been published. The only available pediatric series on CPR quality was not powered to find differences in clinical outcomes, rather this observational study established that CPR errors, specifically shallow chest compressions, occur commonly during the resuscitation of older children and adolescents [Sutton(a), 2009]. Unfortunately, no prospective randomized study comparing quantitative CPR data to clinical outcomes (arterial blood pressure, end tidal CO2, ROSC) has been published.

Chest compressions targeted to 1/2 AP chest depth improved systolic and mean arterial pressure in infants post-cardiac surgery when compared to 1/3 AP depth compressions [Maher, 2009]. While this is the only pediatric study using a clinical hemodynamic outcome to evaluate different chest compression depths, this study was a retrospective case-series of only 6 infants that used qualitative estimations of chest compression depth rather than objective measurements. These data suggest that targeting “deeper” results in better hemodynamics, but the depth of compressions was not measured. In contrast, there are now three pediatric measurement based studies (two radiological [Kao, 2009; Braga, 2009] and one external anthropometric [Sutton(b), 2009]) to suggest that the latter recommendation to compress the chest to 1/2 AP chest depth is not feasible. Braga et.al. found that the residual internal depth after a 1/2 AP depth compression (the depth of the chest cavity that would in theory contain the thoracic organs at maximal compression) would be less than 10mm in over 90% of pediatric patients. These investigations establish that our existing recommendations result in absolute measurement based depths that exceed the current adult recommendations (4 to 5cm which is only on average, 20% of AP chest depth ([Pickard, 2006]). Moreover, as animal models suggest little benefit from increasing compression depth from 4 to 5cm [Wik 1996] and that molding of the chest in younger animals from circular to elliptoid allows higher pressures to be generated with the same depth of compression [Dean, 1987], the recommendation to compress the pediatric chest more than an adult chest may need reevaluation. Concerns for rib fractures and other thoracic injuries, while theoretically a concern with an excessive compression, have not been found to occur more frequently in pediatric patients who received CPR [Maguire, 2006]. However, chest compressions targeted to extremes of myocardial perfusion have caused injury in animal models [Kern,
Important, all three pediatric thoracic measurement studies above suggest that a minimal depth of 1/3 AP chest depth is feasible for providers to attain.

While compression to 1/2 AP depth may not be attainable, there is evidence to suggest that a necessary compression threshold exists above which measurable cardiac output is attained [Babbs, 1983]. Given that improved arterial blood pressure [Ornato, 1989] and short term outcomes [Kramer-Johansen, 2006; Edelson, 2006] are associated with improved compression depth, any future recommendation must take into account CPR providers tendency to fail to meet the minimal compression depth target [Abella, 2005; Wik, 2005; Sutton(a), 2009].

Acknowledgements:

Special thanks to Vinay Nadkarni and Robert A. Berg for worksheet review.

Citation List


Level of Evidence: 5
Quality: Good
Direction: Neutral
Comments: This study was not of the population of interest (LOE 5). Observational; not powered to find differences in clinical outcomes between groups; established that shallow chest compressions were common during in-hospital adult resuscitation attempts.


Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Canine model: minimal compression threshold of 1.5 to 3.0cm required to produce measurable cardiac output.


Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Swine model: mean aortic pressure and total systemic blood flow increased as Thumper piston stroke lengthened from 1.5 to 2 to 2.5 inches.

Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Canine Model: increased chest compression force results in higher perfusion pressures.


Level of Evidence: 5
Quality: Fair
Direction: Supporting
Comments: Observational study looking at non-arrested pediatric patients (LOE 5). CT measurements of infant and child chests demonstrate that chest compressions targeted to 1/2 AP chest depth are not feasible as they result in an internal residual depth less than 10mm in 94% of children; suggests 1/3 minimal depth or 38mm as possible alternative.


Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Swine model: deformity of the chest of younger animals that results after compression (cylinder to elliptic) responsible for higher generated pressures compared to older animals who do not deform.


Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Not of population of interest (LOE 5). Establishes that during adult arrest resuscitation, higher mean chest compression depth prior to defibrillation improves shock success (adjusted odds ratio 1.99 for every 5mm increase). Suggests that deeper compressions improve clinical outcomes.

Level of Evidence: 5
Quality: Fair
Direction: Supporting
Comments: Observational study looking at non-arrested patients (LOE 5). CT measurements of infant and child chests demonstrate that chest compressions targeted to 1/3 to 1/2 AP chest depth will be deeper than adult recommendations (~4-6cm).


Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Canine model: increased chest compression force results in higher perfusion pressures.


Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Canine model: myocardial perfusion pressure predictor of survival, but CPR trauma more prevalent at extremes (near 40mmHg).


Level of Evidence: 5
Quality: Good
Direction: Supporting
Comments: Not of population of interest (LOE 5). During adult resuscitation attempts, increased chest compression depth was associated with increased rate of survival to hospital admission in a logistic regression model. Suggests that deeper compressions improved clinical outcomes.


Level of Evidence: 4
Quality: Good

Direction: Neutral

Comments: Systematic review: rib fractures in children who underwent CPR are rare.


Level of Evidence: 4

Quality: Poor

Direction: Opposing

Comments: Chest compressions targeted to 1/2 AP chest depth resulted in higher systolic and mean intra-arterial blood pressures. Graded as poor as chest compression depths were qualitative estimations, retrospective, small numbers(n=6). Does support current recommendation to target between 1/3 and 1/2 AP chest depth.


Level of Evidence: 5

Quality: Good

Direction: Supporting

Comments: Not of population of interest (LOE 5). Higher compression force improved arterial systolic pressure and flow in human beings receiving closed-chest compression during CPR. Suggests that deeper compressions improve flow.


Level of Evidence: 5

Quality: Fair

Direction: Supporting

Comments: Not of population of interest (LOE 5). CT measurements of adult chest demonstrate that chest compressions targeted to 4-5cm result in depths of approximately 1/5 AP chest depth. Suggests that current pediatric recommendations are targeting towards deeper chest compressions as compared to adults.


Level of Evidence: 5

Quality: Good
Direction: Neutral

Comments: Not of population of interest as these subjects were all greater than 8 years of age (LOE 5). Even with automated feedback assistance, shallow chest compressions are common during in-hospital resuscitation of older children and adolescents.


Level of Evidence: 5

Quality: Fair

Direction: Supporting

Comments: Study of non-arrested children (LOE 5). External thoracic anthropometric measurements of children ages 6m to 8yrs suggests that adult depth of 38mm would not meet minimal depth of 1/3 AP depth frequently. Raises question: do we need to compression children deeper than adults?


Level of Evidence: 5

Quality: Good

Direction: Neutral

Comments: Not of population of interest (LOE 5). Shallow chest compressions common during out-of-hospital adult resuscitation.


Level of Evidence: 5

Quality: Good

Direction: Supporting

Comments: Swine model: increasing compression depth from 4 to 5cm did not improve organ blood flow.