**Clinical question.**

In the absence of a manual defibrillator for infants (< 1 year, not including newly born) in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of AEDs (I) compared with standard management (which does not include use of AEDs) (C), improve outcomes (eg. termination of rhythm, ROSC, survival) (O)?

**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:** New topic.

**Conflict of interest specific to this question**

Intellectual conflict: One of my publications is included in the worksheet.

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

Initial search for: "Cardiac arrest" AND ("infant" OR "children") AND ("defibrillation" OR "electric shock" OR "automated external defibrillation") AND ("outcome" OR "ROSC" OR "survival")


Additional search for:
- Age terms (newborn, infant, child, children, pediatrics, adolescents)
- Procedure terms (defibrillation, electric shock, electric countershock, defibrillation, automated external defibrillation, resuscitation, life support), - Rhythm terms (ventricular fibrillation, ventricular tachycardia, commotio cordis).

**State inclusion and exclusion criteria**

**Inclusion criteria:**
- Age: Initial criteria: from newborn to one year, includes: newborn, neonate, infant, baby. Extended criteria: pediatrics, includes children and, adolescents
- Condition: Cardiac arrest
- Site: In-hospital, Out-of-hospital
- Treatment: Defibrillation, Resuscitation, Life support,
- Languages: All papers with abstract in English. Papers without abstract but with text in Spanish, French, German, Portuguese, Italian were included.

**Exclusion criteria:**
- Age: Adults.
- Condition: Heart disease or condition, but not related with cardiac arrest (eg. Post-op, hemodynamics laboratory), Respiratory arrest.
- Site: Operating room, Hemodynamics laboratory.
- Treatment: Manual defibrillation
- Languages: Papers without abstract in English or in languages other than specified in inclusion criteria.

**Number of articles/sources meeting criteria for further review:** 24
# Summary of evidence

## Evidence Supporting Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th>Fair</th>
<th>Poor</th>
<th>Level of evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>A = Return of spontaneous circulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>B = Survival of event</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>C = Survival to hospital discharge</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D = Intact neurological survival</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>E = Other endpoint</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Italics = Animal studies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>* = overlapping patients</td>
</tr>
</tbody>
</table>

# Evidence Neutral to Clinical question

<table>
<thead>
<tr>
<th>Good</th>
<th></th>
<th></th>
<th></th>
<th>Atkins, 2009, C</th>
<th>Smith, 2006, B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tibbals, 2006, D</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</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  

*Italicics = Animal studies*

# Evidence Opposing Clinical Question

<table>
<thead>
<tr>
<th>Good</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</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  

*Italicics = Animal studies*
In the absence of a manual defibrillator for infants (< 1 year, not including newly born) in cardiac arrest (prehospital [OHCA], in-hospital [IHCA]) (P), does the use of AEDs (I) compared with standard management (which does not include use of AEDs) (C), improve outcomes (eg. termination of rhythm, ROSC, survival) (O)?

In infants in cardiac arrest, shockable collapse rhythms are not common, but they are not exception and may occur in out- and in-of-hospital setting. The National Registry of CPR (NRCPR) (in-hospital cardiac arrest results) reported that 21% of all infants from one month to one year of age had ventricular fibrillation (VF) or pulseless VT (pVT) (Samson 2006). The recent ROC Epistry-Cardiac arrest indicates a VF/VT frequency of 4% in infants with out-of-hospital cardiac arrest (Atkins, 2009).

In a series of children who suffered out-of-hospital or in-hospital cardiac arrest, 25% of those who required defibrillation due to initial or subsequent VF or pVT were infants (Rodriguez-Nunez 2006).

Multiple studies in adults have demonstrated that early defibrillation is an essential therapy in order to achieve intact neurological function survival after VF/VT. Results of pediatric defibrillation are comparable to adults for primary VF/VT, but they have been poor for subsequent VF/VT (Samson 2006, Rodriguez-Nunez 2006).

No studies have been specifically addressed to ascertain the effectiveness of defibrillation (manual or automated) in infants with VF/VT as well as the outcome of resuscitation without electric shocks in such cases.

Automated external defibrillation (AED) is a well established therapy in adults and, from 2005 guidelines, it is also recommended for children older than one year. Due mainly to concerns about accuracy, safety of shocks and effectiveness in infants younger than one year, 2005 guidelines did not make recommendations about AED indication in this age group.

Several studies have demonstrated that current AED devices are accurate for detecting shockable and non-shockable rhythms. Cecchin et al (2001) recorded rhythms in catheterization laboratories, ICUs, and cardiac operating rooms in children aged from 1 day to 12 years. The device used demonstrated good specificity and sensitivity. They included 19 infants and newborns, with 44 shockable rhythms. Sensibility was high and similar for all age groups. Specificity for non-shockable rhythms (59 infants and 208 rhythms) was 100% (similar to the figures for other pediatric ages).

Other studies confirmed that AED devices are accurate (Atkins 2008) but it remains important that each manufacturer test its algorithm against a database of rhythms obtained form infants younger than 1 year. This should be a pre-requisite to use a specific device (Atkins 2008).

Energy waveform: There is substantial evidence on the superiority of biphasic waveforms, based on animal studies as well as multiple clinical studies (in age groups other than infants).

Energy dosing: Optimal effective dosing for manual or automated external defibrillation in children (and infants) has not been established. Doses from 2 to 4 J/kg have been recommended for manual defibrillation. For AED, dose attenuation to 50 Joules is available and recommended for children older than one year.

Indirect evidences have been obtained form animal models. Although direct equivalence of “biological age” between laboratory animals (piglets) and infants cannot be made, it can be assumed that 4 kg piglets have similarities with children <1 month old, and 4-12 kg piglets have similarities with infants. In this sense, there are studies that have demonstrated that AED are safe and effective in infant animal models (Killingsworth 2002, Tang 2002, Berg 2003, Berg 2004, Berg 2005, Berg 2008).
Also, animal studies have indicated that young hearts can resist high doses (Babbs 1980, Gaba 1982, Tang 2002, Killingsworth 2002) and then, if no dose attenuator is available, even adult doses (150 J) could be delivered to children.

No data are available to decide the maximal safe dose in infants. In an animal study using monophasic defibrillator the median toxic energy dose linked with myocardial injury was 30 J/kg (Babbs 1980) and in another study in newborn-pediatric piglets, no persistent myocardial injury was detected in animals that received individual shocks up to 90 J/kg using a biphasic waveform (Killingsworth 2002). However, these data are difficult to extrapolate to the clinical setting mainly due to the anatomic and physiologic differences between animals and humans.

Case reports, although scant, have indicated that high electrical shock doses are effective and safe for terminating VF/pVT in children. Gurnett et al, (2000), reported the case of a 3-year-old child who was defibrillated by his mother using an impedance-adjusted truncated biphasic waveform. He received 9 J/kg and had no evidence of cardiac damage as measured by EKG, cardiac enzymes, troponin I levels, echocardiography, or angiography. Konig et al, (2007) reported a 6 years-old girl that received with success and safety a dose of 7 J/kg. On the other hand, animal studies have showed the advantage (in terms of less myocardial damage and better neurological outcome) of pediatric defibrillation dosage when compared with adult dosage in a pediatric swine model (Berg 2005, Berg 2008).

A post-market, observational study of voluntary reports of uses of pediatric AED pads in children from 2001 to 2004 (Atkins, 2005), collected 27 cases. Shocks were delivered to all VF patients with success (termination of VF and admission to hospital). Non-shockable rhythms were reported in 16 patients, and the AED appropriately did not advise a shock.

Only two infants treated with AED have been reported. Bar-Cohen et al (2005) communicated the case of a 4 months old female with Wolf-Parkinson-White disease who presented her initial cardiac arrest when she was 11 weeks old. At that time, she required cardiopulmonary resuscitation by her parents, paramedics, and emergency room personnel, including four shocks. After accessory pathways ablation and specific parents’ training, she was discharged from hospital with home AED. She suffered a cardiac arrest episode and her parents used AED with success. The delivered dose was 50 J (that means 8 J/kg). Divekar et al (2006) reported the case of a high risk 8 months-old infant, that was discharged home after parents’ training and with a specifically adjusted for size device. When he arrested at home, the parents started CPR with AED. The third defibrillation dose converted VF to perfusing junctional rhythm at 60/minute followed by sinus tachycardia.

Additionally, Lee et al (2005) communicated the case of a 14 months old infant who suffered commotio cordis during accidental fall. The infant was initially resuscitated by first responder personnel (AED was not used because the ambulance had only one adult type device). When they arrived at hospital (ten minutes later) the infant was found in VF and was manually defibrillated after three electric shocks (20,40 and 40 J) and one adrenaline dose. The authors speculate about the possible use of AED in this case (and other similar).

In infants, pad size and placement could be significant factors for defibrillation success but no evidence is available on this topic. For manual defibrillation, “infant paddles” are recommended in infants with weight less than 10 kg. Both apex-parasternal and antero-posterior positions are acceptable, provided the body’s size permits separation between pads.
Conclusion:
- Shockable rhythms can be present in infants in cardiac arrest and prompt defibrillation must be an essential element of life support in these cases.
- AED devices are accurate to detect shockable rhythms in children and infants.
- Optimal energy dose has not been determined but it seems that infants could support the relatively high electric shock doses that are delivered by AED devices even with dose attenuator (50-75 J).
- AEDs have been effective to reverse VF in high-risk infants, when parents had CPR skills and an AED at home.

Significant knowledge gaps for AED in infants remain about:
- Optimal doses, waveforms, pad size and placement.
- Outcome consequences of myocardial damage secondary to high dose electric shocks.
- Effectiveness of AED in non high-risk infants and/or treated by paramedics or other personnel.
- Usefulness of AED in hospital (pediatric areas).
- Public access defibrillation for infants.

Despite these gaps, randomized clinical trials on this topic are very difficult to carry out and they are not expected (due to rarity of the events, vital risk, ethical problems and low economical interest). Then, ongoing registry and analysis of cases may be essential to ascertain the usefulness of AED in infants.

REVIEWER’S CONFLICTS OF INTEREST:


Citation List


LOE 4. Prospective study without controls. Data obtained by voluntary reports of use of attenuating dose pads with biphasic waveform devices. All children received 50 J. Termination of VF was achieved in all indicated cases (8) after 1 to 4 shocks. AED detected non shockable rhythms (and not advise a shock) in 16 patients.


LOE 5. Prospective study that defined specific pediatric rhythm detection criteria after analysing 120 shockable rhythms and 585 non-shockable rhythms. The pediatric-based AED rhythm analysis algorithm demonstrated an overall accuracy of 99.0%.

LOE 4. Prospective population-based cohort study of pediatric OHCA. Patients stratified into 3 groups, one of them infants < 1 year, including 277 cases. 4% had VF/VT and survival was 0%.


LOE 5. Prospective study that collected ECGs from hospitalized children. The records were used to check the accuracy of an AED. Sensitivity was 99% and specificity 99.5%.


LOE 5. Animal study. Design simple and limited but useful for the objective: to try to establish a therapeutic index for defibrillation dosing. Assessment of toxicity was performed by histologic examination. The results indicate a median defibrillating dose of 1.5 J/kg and median toxic dose of 30 J/kg.


LOE 4. Interesting case report of successful parental use of AED in 5 month high-risk infant.


LOE 5. Review of evidences on the treatment of prolonged pediatric defibrillation. The results supports the use of AED for children.


LOE 5. Well designed animal study that compares adult vs. pediatric biphasic waveform AED escalating dosing in a piglet model of prolonged prehospital VF. ROSC was achieved in 15/16 with pediatric dosing vs. 14/16 with adult dosing. Pediatric dosing resulted in fewer elevations of troponin and less depression of left ventricular ejection fraction.

LOE 5. Retrospective study of out-of-hospital CA in a single site. 9% had documented VF. The results were poor, with 2 J/kg (monophasic waveform) terminating VF in 50%, none to a perfusing rhythm and no survivors.


LOE 5. Good study design, randomized. Pediatric animal model (piglets) with long duration VF were defibrillated with attenuated adult dosing vs. standard adult dosing. Unattenuated adult dosing resulted in worse post-resuscitation myocardial function at 4 hours but the animals who received the attenuated dosage required more shocks and survival was similar in both groups.


LOE 4. Prospective recording and digitalization of paper ECGs in children and test for accuracy with a specific AED device. Good specificity (100%) and sensitivity (96%).


LOE 4. Case report of successful parental AED use with excellent outcome in a high risk infant with congenital long-QT syndrome.


LOE 5. Animal study in piglets evaluating the consequences of electric counter shock by means of myocardial uptake of Tc-99m. Results indicate a wide safety margin.


This case report describes a 39 month old child who was successfully defibrillated at home by his mother using an AED delivering an impedance compensated biphasic waveform delivering of 150 J/kg (9 J/kg). Four hours after the shock the child’s cardiac enzymes were normal and echocardiography demonstrated normal ventricular function.

LOE 5. Single case report of successful use of an AED at home in a child with relatively high dosing.

LOE 5. Animal study in "pediatric animals". Biphasic truncated exponential waveform counter shocks were given to piglets to determine the defibrillation threshold and to estimate the myocardial function after shock delivery. Defibrillation threshold was 2.3 J/kg. High dosing produced transient ST segment changes, and hemodynamic alterations. The results indicate a wide safety margin of dosage.


LOE 5. Single case report of successful use of an AED in a child.


LOE 5. Single case report of an infant who survived after commotion cordis during a fall and delayed defibrillation.


LOE 5. Prospective observational multicenter American registry comparing in-hospital cardiac arrest in children vs. adults. Prevalence of VF or pulseless VT as the first documented pulseless rhythm was 14%, that compares with 23% in adults.


LOE 5. Secondary analysis of multicenter prospective registry and combined in- and out-of-hospital pediatric arrests in Spain. Study focused on the results of defibrillation. VF or pulseless VT was the first documented rhythm in 43% of cases and developed during CPR in 57%. The first dose (monophasic waveform 2 J/kg) terminated VF only in 18% of cases. 38.6% needed more than 3 shocks. ROSC was 63.6%.


LOE 5. Retrospective review or prospectively collected data of children from 1 month to 18 years who received shocks for VF out-of-hospital. Outcome limited to survival to hospital discharge. Mean number of shocks was 3, with 75% of instances with high or very high energy doses. Survival was related to duration of CPR, but not to age, electric dosing, total energy or total number of shocks.

*LOE 5. Prospective observational multicenter American registry comparing initial vs. subsequent VF or VT in pediatric (under 18 years) in-hospital cardiac arrest. Survival outcomes were higher in initial VF/VT.*


*LOE 5. Retrospective cohort study of out-of-hospital CA during a long time period (from 1976 to 2003) in children. VF was the presenting rhythm in 7.6% of children aged 1-7 years and 27% among those aged 8-18 years.*


*LOE 5. Controlled randomized animal study (piglets of different sizes-ages) evaluating the effects of 50 J/kg after 7 mins of untreated ventricular fibrillation. Studied outcomes included myocardial function, hemodynamics and survival. All animals were successfully resuscitated.*


*LOE 5. Prospective of in-hospital pediatric cardiac arrest in a single center. VF/VT was present in 10 patients and secondary VF occurred in 15.*