The ABC of CAB-
Circulation, Airway, Breathing:
PALS/Resuscitation Update

Jennifer K. Lee, MD
Johns Hopkins University
Dept. of Anesthesia, Division of Pediatric Anesthesia
Disclosures

• I have research funding from Covidien/Medtronic

• I will not reference an unlabeled/unapproved use of a drug or product in my presentation
Objectives

• Review the new PALS guidelines

• Discuss scientific concepts related to perioperative pediatric resuscitation
2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Circulation 2015; 132(Suppl 2).

(Last AHA guidelines from 2010)
All studies in this presentation were included in the 2015 AHA Guidelines update
Minimize the “No Flow Time”

Mannikin Studies
C-A-B decreases the time to first chest compression in comparison to A-B-C

C-A-B delays the first ventilation by only ~6 seconds when compared to A-B-C

Chest Compressions

- 2010 guidelines
  - “at least” 100 compressions per minute

Kleinman ME, et al. *Circulation* 2010
Chest Compressions – 2015 AHA Guidelines

• New chest compression rate of 100 to 120/minute for infants and children
  – Insufficient pediatric data about compression rate
  – Use the adult BLS rate
  – Simplify CPR training

Optimize Chest Compressions

**FAST**
100-120/minute

**HARD**
(at least 1/3 AP chest diameter)

**FULL RECOIL**

**MINIMIZE INTERRUPTIONS**

Atropine

• 2010 guidelines
  – Atropine dose 0.02 mg/kg
  – Minimum dose of 0.1 mg due to potential “paradoxic bradycardia”

Kleinman ME, et al. *Circulation* 2010
Atropine Prior to Intubation (PICU, Transport team)

Atropine (0.02 mg/kg; no minimum dose) decreased the incidence of junctional and atrial ectopic rhythms.

Proportion of arrhythmias vs. Heart Rate (bpm) for intubations (< 8 years old), with n = 327 intubations.

Jones P, et al., Ped CCM 2013
Atropine Prior to Intubation
(Emergency Dept. of Level 1 Trauma Center)

<table>
<thead>
<tr>
<th>81 Patients Met ACEP Criteria for Atropine Treatment</th>
<th>Atropine Group, 49 (60%)</th>
<th>No-Atropine Group, 32 (40%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to L/TI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median age, months</td>
<td>1.4</td>
<td>9</td>
<td>0.76</td>
</tr>
<tr>
<td>Average no. L/TI attempts/patient</td>
<td>1.6</td>
<td>1.5</td>
<td>0.47</td>
</tr>
<tr>
<td>Bradycardia (%)</td>
<td>2 (4%)</td>
<td>1 (3%)</td>
<td>0.4</td>
</tr>
<tr>
<td>Hypoxia (%)</td>
<td>18 (37%)</td>
<td>7 (22%)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

No difference in the incidence of bradycardia or hypoxia between children that received atropine (n=49) and those that did not receive atropine (n=32)

Atropine – 2015 AHA Guidelines

• Specifically for emergency intubations

• **Routine** use of atropine is **not** supported for critically ill infants and children

• Reasonable to use atropine prior to intubation when clinician anticipates a higher risk of bradycardia (i.e. succinylcholine)

• Atropine dose: 0.02 mg/kg

• **No minimum dose** for atropine

In-Hospital Cardiac Arrest + E-CPR

• “E-CPR” = extracorporeal cardiopulmonary resuscitation (ECMO or cardiopulmonary bypass)
  – Example: Use of ECMO/ bypass for cardiac arrest that requires chest compressions and/or defibrillation

• 2010 guidelines
  – Consider ECMO for cardiac arrest refractory to conventional interventions
  – When managing a reversible underlying disease process

In-Hospital Cardiac Arrest + E-CPR

n = 199 children (84% arrests in O.R. or PICU)

Survival rates were higher in patients with cardiac illness than in those with non-cardiac illness ($p = 0.006$)

Raymond TT, et al. Ped CCM 2010
In-Hospital Cardiac Arrest – 2015 AHA Guidelines

• Consider E-CPR for patients with cardiac diseases
  – Includes congenital cardiac malformations

• Institutions with existing ECMO/bypass protocols, expertise, and equipment

End-Tidal CO\textsubscript{2} (ETCO\textsubscript{2}) Monitoring

- 2010 guidelines
  - During CPR, goal ETCO\textsubscript{2} > 15 mmHg
  - If ETCO\textsubscript{2} is less than 15 mmHg:
    - Improve chest compressions
    - Avoid excessive ventilation

Kleinman ME, et al. *Circulation* 2010
ETCO₂ Monitoring: Piglet model of pediatric V-fib cardiac arrest & CPR

- “Optimized”: 100 compressions/min; depth 1/3 A-P diameter
- ETCO₂-guided: obtain maximal ETCO₂

ETCO₂-guided CPR was as good as optimized standard CPR in achieving ROSC

ETCO₂-directed + survive

ETCO₂-directed + die

100/min; depth 1/3 AP diameter + survive

ETCO₂ Monitoring– 2015 AHA Guidelines

• No pediatric evidence that ETCO₂ monitoring improves outcome after cardiac arrest
  – Little existing research on this topic

• Consider ETCO₂ monitoring to evaluate the quality of chest compressions

• Specific ETCO₂ values to guide therapy have not been established in children

Shock Refractory V-fib or Pulseless V-Tach

- 2010 guidelines
  - Amiodarone was the preferred medication over lidocaine

Shock Refractory V-fib or Pulseless V-Tach
Observational (retrospective) study from 242 hospitals
n = 889 children

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>ROSC</th>
<th>Survive 24 hours</th>
<th>Survive to hospital discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amiodarone only</td>
<td>89</td>
<td>44%</td>
<td>30%</td>
<td>17%</td>
</tr>
<tr>
<td>Lidocaine only</td>
<td>213</td>
<td>64%</td>
<td>47%</td>
<td>25%</td>
</tr>
</tbody>
</table>

Children who received lidocaine had higher rates of attaining ROSC ($p=0.002$) and of surviving for 24 hours ($p=0.01$) than those who received amiodarone.

Shock Refractory V-fib or Pulseless V-Tach Multivariate analysis

• Amiodarone was not associated with ROSC or survival

• **Lidocaine improved odds** \((p<0.05)\) of **attaining ROSC** and **24-hour survival** after controlling for:
  
  – Cardiovascular and respiratory support  
  – Cardiac surgery  
  – Trauma  
  – **Arrest in operating room or PACU**  
  – Duration of arrest/ resuscitation  
  – Number of defibrillation attempts  
  – Number of epinephrine doses  
  – Time to defibrillation

Shock Refractory V-fib or Pulseless V-Tach – 2015 AHA Guidelines

• Either amiodarone or lidocaine

• Lidocaine 1 mg/kg IV or IO loading dose
  – Maintenance: 20-50 mcg/kg/minute infusion
  – Repeat bolus dose if infusion is initiated >15 minutes after the initial bolus

• Amiodarone 5 mg/kg IV or IO
  – Repeat up to 2 times

Shock Refractory V-fib or Pulseless V-Tach – 2015 AHA Guidelines

V-fib, Pulseless V-tach

CPR for 2 min
Shock
CPR for 2 min
Shock
Amiodarone or lidocaine

© 2015 American Heart Association

Shock Dose for V-fib or Pulseless V-Tach

- Relatively few clinical pediatric studies about shock dose
- The optimal shock dose remains unclear
Shock Dose for V-fib or Pulseless V-Tach
In-hospital cardiac arrests at 82 hospitals
n=258 children (29% surgical cardiac; 6% surgical non-cardiac)

Initial shock dose did not affect rates of terminating V-fib/V-tach or of attaining ROSC
-When the initial shock dose was 3 - 5 J/kg, the child was less likely to survive ($p=0.05$)

## Shock Dose for V-fib or Pulseless V-Tach

In-hospital cardiac arrests

*n = 40 events in 37 children (1 month – 18 years old)*

<table>
<thead>
<tr>
<th>Dose per shock</th>
<th>ROSC (%)</th>
<th>p</th>
<th>Survive to hospital discharge (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2 J/kg</td>
<td>50</td>
<td>0.107</td>
<td>25</td>
<td>0.575</td>
</tr>
<tr>
<td>2-4 J/kg</td>
<td>57</td>
<td></td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>&gt;4 J/kg</td>
<td>100</td>
<td></td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of shocks</th>
<th>p</th>
<th>Survive to hospital discharge (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3</td>
<td>0.266</td>
<td>70</td>
<td>48</td>
</tr>
<tr>
<td>&gt;3</td>
<td></td>
<td>46</td>
<td>27</td>
</tr>
</tbody>
</table>

Shock Dose for V-fib or Pulseless V-Tach – 2015 AHA Guidelines

- Overall unchanged from the 2010 guidelines

- Initially 2 to 4 J/kg of monophasic or biphasic energy for defibrillation
  - Can use 2 J/kg for “ease of teaching”

- Increase to 4 J/kg, and can consider higher subsequent energy levels

- Do not exceed 10 J/kg or the adult maximum dose

Post-Arrest Temperature – 2015 AHA Guidelines

- Avoid and aggressively treat fevers (temperature >38°C)

- Still awaiting results of Therapeutic Hypothermia After Pediatric Cardiac Arrest (THAPCA) In-hospital cardiac arrest arm

Post-Arrest Temperature – 2015 AHA Guidelines

• THAPCA Out-of-hospital cardiac arrest arm
  – No difference in survival or functional outcome at 1 year between therapeutic hypothermia and normothermia groups
  – Median time to induce hypothermia was 5.9 h
  – Study may be underpowered

Moler FW, et al. NEJM 2015
Post-Arrest Oxygen

n = 1875 IH or OH cardiac arrests (<16 yo)

Risk of death estimates for OH cardiac arrest:

Mortality risk was lowest when PaO2 ~60 – 75 mmHg within 1 h after ROSC

Congenital Heart Disease

No congenital Heart Disease

Post-Arrest Oxygen – 2015 AHA Guidelines

• Maintain normoxemia

• Arterial oxyhemoglobin saturation of 100% may correspond to PaO$_2$ between 80 and ~500 mmHg

  – Wean the oxygen to target an oxyhemoglobin saturation $\geq$94% and <100%

  – Goal is to achieve normoxemia but ensure that hypoxia is strictly avoided

Post-Arrest CO₂ – 2015 AHA Guidelines

In-hospital cardiac arrest

*n = 223 (1 month to 18 years old)*

<table>
<thead>
<tr>
<th>PaCO₂ immediately after ROSC</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th><em>p</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;50 mmHg</td>
<td>3.27</td>
<td>1.62–6.61</td>
<td>0.001</td>
</tr>
<tr>
<td>&lt;30 mmHg</td>
<td>2.71</td>
<td>1.04–7.05</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Both hypercapnia and hypocapnia immediately after ROSC were associated with in-hospital death after controlling for:

- Respiratory illness
- Initial rhythm
- Type of arrest
- Duration of CPR
- Location of arrest (PICU)

Post-Arrest CO₂ – 2015 AHA Guidelines

• Limit exposure to severe hypercapnia or hypocapnia

• Target a PaCO₂ that is appropriate for the specific patient condition
Post-Arrest Blood Pressure

n = 228 non-traumatic out-of-hospital cardiac arrests

Mean arterial blood pressure (MAP) During 1st hour after ROSC (by age-appropriate norms)

Lin YR, et al. Resuscitation 2010
Post-Arrest Blood Pressure – 2015 AHA Guidelines

• Use IV fluids and/or inotropic or vasoactive medications to maintain systolic blood pressure greater than 5th percentile for age

• Continuous arterial blood pressure monitoring

• No studies on whether specific vasoactive agents are preferable

Septic Shock

- Very difficult to treat during anesthesia and surgery

- 2010 guidelines
  - Avoid “routine” use of Etomidate for intubation
  - Little information on fluid bolus amounts

Septic Shock (United States)

Sepsis = positive blood culture or organism identified from tissue

Shock = Blood pressure less than 2 SDs below the mean for age plus deceased peripheral pulses, mottled/cool extremities, tachycardia, or urine output <1 mL/kg/hr

n = 34 children (1 month – 16 years old)

Fluid in first hour (mL/ kg)

Carcillo JA, et al. JAMA 1991
Pediatric Sepsis – Africa (Kenya, Tanzania, Uganda; malaria)
Fluid boluses ~20 – 100 cc/kg or no bolus

Cumulative Probability of Death at 48 HOURS

No. children at risk of death at each time point: 954–1050/ group (60 days - 12 years old)

Maitland K, et al. NEJM 2011
Pediatric Sepsis – Africa (Kenya, Tanzania, Uganda; malaria)
Fluid boluses ~20 – 100 cc/kg or no bolus

Cumulative Probability of Death at 4 WEEKS

Saline or Albumin boluses
No bolus

No. children at risk of death at each time point:
897–1050/ group (60 days - 12 years old)

Maitland K, et al. NEJM 2011
Septic Shock – Crystalloid vs. Colloid

Heart rate (bpm)

Systolic, diastolic blood pressure (mmHg)

CVP (cm-H₂O)

n = 60 children (1 month – 12 years old)

Normal saline: solid line
Colloid gelatin: dotted line

Upadhyay M., et al. Indian Pediatri 2005
Septic Shock – 2015 AHA Guidelines

• Give initial fluid bolus of 20 mL/kg
• Give bolus IV fluids with caution in settings with limited access to critical care resources
• Carefully assess the patient before proceeding with the next bolus
• Use either isotonic crystalloids or colloids

Conclusions

• 2015 AHA Guideline Updates
  – Compressions: 100 – 120 per minute
  – Atropine not routinely recommended for intubation
  – No minimum dose for Atropine
  – Lidocaine can be used to treat V-fib, pulseless V-tach
Conclusions

- 2015 AHA Guideline Updates

  - Reduce FiO$_2$ after attaining ROSC to maintain SaO$_2$ $\geq$ 94% but less than 100%

  - Activate ECMO early, including for congenital cardiac disease
Conclusions

• 2015 AHA Guideline Updates

– Consider conservative fluid resuscitation in sepsis

– We should use ETCO$_2$ to guide quality of chest compressions in the operating room

• Studies are needed on the impact of ETCO$_2$ monitoring during CPR in the operating room