Monitoring CPR Quality in Infants and Children

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Conflict of interest

Financial

- None

Academic/ Intellectual:

- International Liaison Committee on Resuscitation (ILCOR)
- Heart and Stroke Foundation of Canada
- American Heart Association
Objectives

- What is high quality pediatric CPR?
  - Chest compression depth
  - Chest compression rate
  - Chest compression release/leaning
  - Avoidance of hyperventilation
  - Minimizing interruptions in chest compressions

- How do we measure it?
- How do we teach it?
- Do we practice it during real resuscitations?
- Does targeting metrics of high quality CPR alter pediatric cardiac arrest outcomes?
Do we consistently provide high quality CPR to older children (>8 yrs age)?

*Sutton, Pediatrics, 2009*

- Observational study of CPR quality in PICU/ Peds ED
- Patients >8 yrs age
- CPR recording/feedback defibrillators (Phillips MRX and Q-CPR software)

**2005 resuscitation standards**
- CC depth 38 mm (1.5 in)
- CC rate 90-120 / minute
FIGURE 1
Percentage of time segments of analyzed CPR that met AHA standards. Y indicates met AHA standards; N indicates outside AHA standards.
Do we consistently provide high quality CPR to young children (<8 yrs. age)?

*Sutton, Resuscitation, 2013*

Fig. 3. Percentage of CPR epochs achieving targets for depth $\geq 50$ mm, rate $\geq 100$ and $\leq 120$ CC/min, CC fraction $>0.80$, and leaning $<20\%$ of compressions. Excellent indicates CPR having all 4 CPR elements achieving targets.
What do chest compressions do?

The critical effect of chest compressions is generation of coronary artery perfusion pressure (CPP)

CPP is the surrogate (animal and human studies) for ROSC (return of spontaneous circulation)
• Only patients (total n=100) with max. CPP of > 15 mm Hg had ROSC
• Likelihood of ROSC increased as CPP increased
In the absence of invasive lines, how do we measure CPR quality?

> 1/3 of anterior-posterior diameter

1.5-2” (4-5 cm)
Radiographically, how deep is too deep?

*Braga, Pediatrics, 2009*

280 consecutive chest CT for each of 14 age divisions between 0 and 8 years were reconstructed and analyzed.

**FIGURE 1**
CT scan demonstrating axial image at the midternal level and method for calculating external and internal chest depth.
Compressing too deeply in infants and small children?  
Braga, Pediatrics, 2009

1/3 external AP chest depth or >38 mm depth seems radiographically appropriate for children 3m to 8 yrs.  

1/2 external AP Diameter or 50 mm too deep??
Comparison of relative and actual chest compression depths during cardiac arrest in children, adolescents, and young adults

Niles, Resuscitation, 2012

- 68% of chest compressions didn't reach 38mm (corrected for mattress compression), the CC-depth targeted for infants
- A CC-depth of 38mm didn't reach 1/3 APD in any subject, let alone 1/2 APD
- >50mm appears more appropriate in older children??
2010 American Heart Association recommended compression depths during pediatric in-hospital resuscitations are associated with survival

*Sutton, Resuscitation, 2014*

- Observational study of children receiving CPR in CHOP’s PICU/ Peds ED
- 78 monitored events between 2006 and 2013
- Quantitative data capture (Philips Heart Smart and Q-CPR)
2010 American Heart Association recommended compression depths during pediatric in-hospital resuscitations are associated with survival

*Sutton, Resuscitation, 2014*

- No adjustment for mattress compression!! (subtract 13mm)
- Only 8/78 pts <8 yrs.
- No patients <1 yr.
Associations between CC-depth and hemodynamics: CC-Guide for the invasively monitored pediatric patient

**Fig. 1.** BP response and depth of compression during CPR. (top) CPR being performed in an infant at 1/2 the thoracic diameter, changing to 1/3rd the diameter with marked reduction in systolic blood pressure. In the bottom strip, CPR is being performed at 1/3rd the thoracic diameter, then increased to 1/2 thoracic diameter resulting in increased systolic pressure. Diastolic blood pressures are unchanged when depth of sternal compressions occur in each patient.

*Maher, Resuscitation, 2009*
American Heart Association cardiopulmonary resuscitation quality targets are associated with improved arterial blood pressure during pediatric cardiac arrest

*Sutton, Resuscitation, 2013*

- 9 children and adolescents (1.75-17 yrs; mean 14 yrs) who suffered a cardiac arrest with an invasive arterial catheter in place

- A CPR monitoring defibrillator collected CPR data which was synchronized to arterial BP tracings

- CC-depth corrected for mattress deflection

- Associations derived between BP and CPR-quality performance metrics

- 4156 CC’s analyzed
Clinically, depth was the performance metric most associated with systolic pressure:

- for every 10 mm increase in CC depth, average systolic BP improved > 15 mmHg

Exceeding both (rate ≥100/min and depth ≥38 mm corrected) was associated with:

- systolic BP ≥80 mmHg (OR 2.02; CI95 1.45, 2.82; p < 0.001)
- diastolic BP ≥30 mmHg (OR 1.48; CI95 1.01, 2.15; p = 0.042)
Pediatric CC Depth in CPR: More questions than answers?

- CC-depth measurement: a need to compare “apples to apples”
  - *Adjust for mattress compression!*

- ⅓ AP diameter adequate for infants but insufficient for older children?

- ⅓ AP diameter excessive for all infants/children?
  - *Is there a “too deep/ TOO HARD” for pediatric CPR?*

- Strive for >50mm (mattress) uncompensated CC-depth, or >38mm compensated CC-depth?
Pediatric CC Depth in CPR: More questions than answers?

- More studies with larger numbers of patients and of younger ages are needed to support evidence-based guidelines for Pediatric CC-depth.
- Why do we (and can we accurately) teach a proportionate depth (⅓ vs. ½) that changes with patient size?
- What is the best way to teach CC-depth in mm?
  - Is there any way to distinguish 38mm from 50mm without the use of feedback devices?
CC rate and Quality of Pediatric CPR

Berg, Acad Emerg Med, 1994 (n=6)
CC rate and Quality of Pediatric CPR

Sutton, Resuscitation, 2013

A rate $\geq 100$/min was associated with:

- systolic BP $\geq 80$ mmHg (OR 1.32; CI95 1.04, 1.66; $p = 0.02$)

- diastolic BP $\geq 30$ mmHg (OR 2.15; CI95 1.65, 2.80; $p<0.001$).

Pediatric outcome data?
CC rate and Quality of Pediatric CPR: What is the best way to teach it/monitor for it?
Leaning during CPR reduces chest wall recoil and impedes venous return, reducing both CPP and cerebral perfusion.
Leaning is common during in-hospital pediatric CPR, and decreased with automated corrective feedback

*Niles, Resuscitation, 2009*

- In-hospital pediatric cardiac arrests (children $\geq 8$ yrs)
- A feedback-capable monitor/defibrillator with force transducer and accelerometer recorded:
  - Chest compression leaning force
  - Leaning depth
- If enabled, audiovisual prompts were given when leaning force exceeded 2.5 kg
• N=20 children (mean age 14.7 +/- 3.8 yr)
• Leaning force > 2.5 kg
  • No feedback: 50%
  • With feedback: 27%
• Any published clinical outcome data? (None in peds)
Quantifying the physiologic effectiveness of CCs

End tidal CO2 will rise as pulmonary blood flow and overall cardiac output rises, assuming that the amount of ventilation (tidal volume and rate) does not change.

- How best to teach/monitor for consistent (breath to breath) ventilation during resuscitation?

Jin, CCM, 2000

![Graph showing correlation between ETCO2 and Cardiac Index]

Jin, CCM, 2000
2010 AHA Guidelines : Using EtCO2 during CPR

- Adult and animal data suggests that a failure to increase EtCO2 to >10 mm Hg during CPR should prompt a change in CPR technique or drug therapy

- No pediatric data…
1. Less interruptions in compressions
2. Faster compressions
3. Deeper compressions
4. Reduce leaning between compressions
5. Stop hyperventilation
6. Give vasopressors
Killing CPR victims with hyperventilation?

Aufderheide et al, Circulation, 2004
Ventilation rate and CPR

- Adults with out of hospital cardiac arrest (OHCA) are frequently ventilated (rate of 37+/− 4 bpm)
  
  **Aufderheide et al, Circulation, 2004**

- Adults with an in hospital cardiac arrest (IHCA) are frequently hyperventilated during resuscitation
  
  - < 10 bpm 7.3%
  - > 20 bpm 60.9%

  **Abella BS, JAMA, 2005**

- Children >8yrs having an IHCA are frequently hyperventilated during resuscitation
  
  - >10 bpm 63%
  - >20 bpm 20%

  **McInnes, Resuscitation, 2011**
Published clinical outcome data? (None in pediatrics)
Other measures to improve Pediatric CPR Quality

- Rotating out fatigued rescuers
  - *Leaning (??), CC depth (??), CC rate: Q2 min?*
- Raising bed for tall rescuers/compressors
  - *leaning*
- Step-stools for short rescuers/compressors
  - *CC depth*
- Minimize mattress compression effects
  - *Consistent use of backboards*
- Post-resuscitation debriefing
  - *??*
Contextual Monitoring of Pediatric CPR Quality: Physiologic vs. Rescuer Performance Metrics

ED/ Pre-hospital (no advanced airway)
1. CC-depth (with feedback/ mattress compensated?)
2. CC-rate
3. Avoidance of hyperventilation and leaning

ED/ Pre-hospital (advanced airway)
1. EtC02
2. Rescuer performer metrics (see below)

In the ICU (already intubated/ invasively monitored)
- CPP/ BPs/ BPd/ EtC02
Monitoring Physiological Response to Resuscitation (Adults)

1. Invasive Monitoring: CPP >20 mm Hg
2. Arterial Line Only: BPd >25 mm Hg
3. Capnography Only: EtC02 >20 mm Hg
Fig. 3. Percentage of CPR epochs achieving targets for depth $\geq 50$ mm, rate $\geq 100$ and $\leq 120$ CC/min, CC fraction $>0.80$, and leaning $<20\%$ of compressions. Excellent indicates CPR having all 4 CPR elements achieving targets.
Real-time feedback can improve infant manikin cardiopulmonary resuscitation by up to 79%: A randomized controlled trial

Martin, Resuscitation, 2013

Fig. 3. Overall quality index scores for the two-thumb (TT) and two-finger (TF) chest compression techniques as performed by both the feedback and control groups at the experimental stage. Data are presented as mean values with 95% confidence intervals.
Near Infrared Spectroscopy during CPR

Nagdyman, BJA, 2003
Venous Oxygen Saturation Monitoring During CPR

Fig. 1. Representation of ScvO₂, ETCO₂ and blood pressure (BP) changes during CPR. DC indicates defibrillation; ROSC, return of spontaneous circulation with palpable pulses. The white arrows denote the intravenous administration of epinephrine.
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Thank you for your attention!

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FIGURE 1. Changes in ETCO₂ during CPR in an experimental model of asphyxia-induced cardiac arrest.