Controversies in Chest Compressions & Airway Management During CPR

Bob Berg
No Financial Conflicts of Interest

• Employment: University of Pennsylvania
• AHA Volunteer
  – AHA GWTG-R & Systems of Care committees
  – Past Chair, GWTG-R Committee
  – Past Chair, BLS Committee
  – Past Chair, PALS Committee
  – 2015 ILCOR BLS Evidence Evaluation
  – 2015 AHA Systems of Care Guidelines
• Grants: NICHD, NHLBI
• Intellectual Conflicts of Interest
  >25 yrs of Cardiac Arrest & CPR Research
Introduction

Chest compressions
  – Hands-only CPR
  – “Physiologic-directed/patient-centered CPR”

Tracheal Intubation during in-hospital CPR
“Closed-chest massage”
Kouwenhoven, Jude, Knickerbocker, JAMA 1960

• While studying defibrillation in small dogs
  – Ao pressure increased with paddles
  – Adequate circulation for 30 min of CC-only CPR

• 20 patients: asphyxia in peri-op setting
  – 20/20 survived the cardiac arrest
  – 14/20 long-term survivors
Arterial Blood Pressure during CPR

Jude, JAMA 1961

Fig. 3.—Examples of arterial blood pressure developed with external cardiac massage. Age and site of chest did
CCC-CPR vs “Standard CPR” for VF
24-48 Hr Survival in 169 swine in 6 studies

<table>
<thead>
<tr>
<th></th>
<th>24-48 Hour Neurologically Normal Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCC-CPR</td>
<td>80%</td>
</tr>
<tr>
<td>Std-CPR</td>
<td>73%</td>
</tr>
<tr>
<td>No CPR</td>
<td>7%</td>
</tr>
</tbody>
</table>

University of Arizona Sarver Heart Center CPR Research Group
Why isn’t Rescue Breathing necessary initially for VF?

• Excellent SaO$_2$ at time of VF

Rescue breathing is life-saving for asphyxia cardiac arrests


• Compression-induced ventilation
Survival by Layperson Bystander CPR Type

Adj OR 1.59 (95% CI: 1.08, 2.35) vs conventional CPR

No CPR: 5.2% (52/666) - 150/2900
Conventional CPR: 7.8% (113/849)
Hands-only CPR: 13.3%

Bobrow, Spaite, Berg et al. JAMA 2010
Dissemination of CC-only CPR and Survival after adult OHCA

816,835 OHCAs

- No CPR: 57.1%
- CC-only CPR: 30.6%
- Conventional CPR: 12.3%

Iwami, Circulation 2015
## Dissemination of CC-only CPR and Survival after adult OHCA

<table>
<thead>
<tr>
<th></th>
<th>CC-CPR (n=249,970)</th>
<th>Conventional CPR (n=100,469)</th>
<th>No CPR (n=465,946)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prehospital ROSC</td>
<td>15818 (6.3)</td>
<td>7982 (7.9)</td>
<td>24163 (5.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>1-month survival</td>
<td>10685 (4.3)</td>
<td>5717 (5.7)</td>
<td>16636 (3.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CPC 1 or 2</td>
<td>4846 (1.9)</td>
<td>2690 (2.7)</td>
<td>5762 (1.2)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Iwami, Circulation 2015
Dissemination of CC-only CPR and Survival after adult OHCA

Figure 3. Trends in the incidence of survival with favorable neurological outcome per 10 million population, attributed to the type of bystander-initiated cardiopulmonary resuscitation (CPR). The trends were tested with Poisson regression models.

Iwami, Circulation 2015
Dispatcher-assisted CPR RCTs

Meta Analysis

<table>
<thead>
<tr>
<th>Study name</th>
<th>Risk ratio</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>Z-Value</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rea et al. NEJM 2010</td>
<td>1.136</td>
<td>0.889</td>
<td>1.451</td>
<td>1.018</td>
<td>0.309</td>
</tr>
<tr>
<td>Svensson et al., NEJM 2010</td>
<td>1.293</td>
<td>0.899</td>
<td>1.859</td>
<td>1.385</td>
<td>0.166</td>
</tr>
<tr>
<td>Hallstrom et al., NEJM 2000</td>
<td>1.398</td>
<td>0.882</td>
<td>2.216</td>
<td>1.425</td>
<td>0.154</td>
</tr>
</tbody>
</table>

Risk ratio and 95% CI

- Rea et al. NEJM 2010: 1.136 (0.889, 1.451) p = 0.309
- Svensson et al., NEJM 2010: 1.293 (0.899, 1.859) p = 0.166
- Hallstrom et al., NEJM 2000: 1.398 (0.882, 2.216) p = 0.154

Hupfl, Lancet 2010
“High quality CPR is the primary component influencing survival”

“Monitor CPR,” but what targets?
Measure CC Rate, Depth, and Leaning
CPR QUALITY MAKES A DIFFERENCE

Sutton, *Resuscitation* 2014
Do we have the right CPR targets to monitor?

**Rescuer-centric** goals (2 inches/5 cm) versus **Patient-centric** hemodynamic goals
Coronary Perfusion Pressure
Critically Important for Successful CPR

CoPP >20 mmHg; AoD >30 mmHg

Sanders, CCM 1984
Michael, Circ 1984
Kern, Resus 1988
Crile, Expt Med 1906
Coronary Perfusion Pressure during CPR
Adult OHCA

Paradis, JAMA 1990
Blood Pressure Guided CPR Improve Outcomes In Swine Cardiac Arrest Model

BP-Guided Care
- CC depth titrated to SBP > 100 mmHg
- If CPP < 20 mmHg, Epi 0.02 mg/kg qmin prn x 2, then vasopressin 0.4 U/kg. Repeat sequence after 2 min prn
- 5/8 (63%) favorable neurologic outcome

Standard Guideline Care (provider-centric)
- Standard CC depth
- Epi 0.02 mg/kg every 4 minute
- 0/8 (0%) favorable neurologic outcome

Sutton AJRCCM 2014, Sutton Resus 2013; Friess CCM 2013; Naim CCM 2016; Morgan Resus 2017
Relationship of Arterial DBP (from start of CPR until up to 10 minutes) with Survival Outcomes

Berg, Sutton, Nadkarni & CPCCRN investigators

PAS Abstract 2017
Index CPR Events ≥ 1 min

N = 164

ROSC > 20 min 112 (68%)
Survival to discharge 77 (47%)
Favorable neuro outcome 70 (43%)

Mean DBP ≥ 25 mmHg (infants) or ≥ 30 mmHg Children
N = 101 (62%)

ROSC > 20 min 75 (74%)
Survival to discharge 55 (54%)
Favorable neuro outcome 49 (49%)

Mean DBP < 25 mmHg (infants) < 30 mmHg (children)
N = 63 (39%)

ROSC > 20 min 37 (59%)
Survival to discharge 22 (35%)
Favorable neuro outcome 21 (33%)
### Association of mean DBP $\geq$25/30mmHg with Outcomes (N=163)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>aRR (95%CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC</td>
<td>1.2 (1.0, 1.6)</td>
<td>0.07</td>
</tr>
<tr>
<td>Surv to d/c</td>
<td>1.7 (1.2, 2.6)</td>
<td>0.003</td>
</tr>
<tr>
<td>Survive with Favorable Neuro</td>
<td>1.6 (1.1, 2.5)</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Waveform Capnography During CPR

B. Capnography to monitor effectiveness of resuscitation efforts. This second capnography tracing displays the $P_{ETCO_2}$ in mm Hg on the vertical axis over time. This patient is intubated and receiving CPR. Note that the ventilation rate is approximately 8 to 10 breaths per minute. Chest compressions are given continuously at a rate of slightly faster than 100/min but are not visible with this tracing. The initial $P_{ETCO_2}$ is less than 12.5 mm Hg during the first minute, indicating very low blood flow. The $P_{ETCO_2}$ increases to between 12.5 and 25 mm Hg during the second and third minutes, consistent with the increase in blood flow with ongoing resuscitation. Return of spontaneous circulation (ROSC) occurs during the fourth minute. ROSC is recognized by the abrupt increase in the $P_{ETCO_2}$ (visible just after the fourth vertical line) to over 40 mm Hg, which is consistent with a substantial improvement in blood flow.
End-Tidal CO$_2$ is Proportional to Cardiac Output During Swine CPR


Normal Cardiac Index 2.6-4.2 ml/min/m$^2$
ETCO\textsubscript{2} in adult OHCA

Sanders, JAMA 1989
End-Tidal $\text{CO}_2$ Prognostication during CPR

### TABLE 1. End-Tidal Carbon Dioxide Values in Patients Who Survived to Hospital Admission and in Those Who Did Not.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>NONSURVIVORS (N = 115)</th>
<th>SURVIVORS (N = 35)</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean ± SD (range)</td>
<td>mean ± SD (range)</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>68.0 ± 15.8 (31–95)</td>
<td>73.5 ± 13.0 (27–90)</td>
<td>0.19</td>
</tr>
<tr>
<td>End-tidal carbon dioxide (mm Hg)</td>
<td>12.8 ± 4.8 (2–50)</td>
<td>12.8 ± 4.8 (5–28)</td>
<td>0.98</td>
</tr>
<tr>
<td>Initial</td>
<td>4.4 ± 2.9 (0–10)</td>
<td>32.8 ± 7.4 (18–58)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Final</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P values were calculated with the Wilcoxon rank-sum statistic.

†Initial end-tidal carbon dioxide levels were determined immediately upon intubation. Final end-tidal carbon dioxide levels were determined after 20 minutes of advanced cardiac life support.

Levine NEJM 1998
Although no clinical study has examined whether titrating resuscitative efforts to physiologic parameters during CPR improves outcome, it may be reasonable to use physiologic parameters (quantitative waveform capnography, arterial diastolic pressure) when feasible to monitor and optimize CPR quality, guide vasopressor therapy, and detect ROSC. (Class IIb, LOE C-EO)
# Potential CPR Physiologic Goals

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Futility</th>
<th>Goal</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronary Perfusion Pressure</td>
<td>&lt;15 mmHg</td>
<td>&gt;25 mmHg</td>
<td>Paradis 1990, Kern 1988</td>
</tr>
<tr>
<td>Arterial Relaxation Pressure</td>
<td>&lt;20 mmHg</td>
<td>&gt;30 mmHg</td>
<td>Paradis 1990, Berg abstr 2017</td>
</tr>
<tr>
<td>End-Tidal CO$_2$ (PetCO$_2$)</td>
<td>&lt;10 mmHg</td>
<td>&gt;20 mmHg</td>
<td>Levine 1998</td>
</tr>
</tbody>
</table>

Modified from Neumar 1/21/17
Tracheal Intubation during Pediatric CPR

Hypothesis: “Tracheal intubation during cardiac arrest would be associated with improved outcome”

2294 time-dependent propensity matched IHCAs

Survival to Hospital Discharge

36% TI vs 41% not TI during CPR

aRR 0.89 (95%CI 0.81-0.99), P=0.03

Mechanism: ? interruptions, CPR quality, bag-mask often adequate?

Message: TI during CPR is high risk

Andersen, JAMA 2016
Tracheal Intubation during Adult CPR

86,628 time-dependent propensity matched IHCAs

**Survival to Hospital Discharge**

16.3% TI vs 19.4% not TI

\[ \text{aRR 0.84 (95\%CI 0.81-0.87), P<0.001} \]

Favorable Neuro (CPC 1 or 2): \[ \text{aRR 0.97 (95\%CI 0.75-0.81)} \]

Although the study design does not eliminate potential for confounding, these findings do not support early tracheal intubation for in-hospital cardiac arrest

Andersen, JAMA 2016
Conclusion

Chest compressions

– Hands-only CPR can be life-saving
– “Physiologic-directed/patient-centered CPR” is the way of the future

Tracheal Intubation during CPR is a high risk intervention