Increasing Compression Rate and Depth Positively Correlate with End-Tidal Carbon Dioxide During Actual CPR Performance

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Presenter: no disclosures

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Concept: Physiologic based CPR

- Antibiotics: Patient with pneumonia
- Temp curve WBC count
- CPR: Patient with Cardiac arrest
- ETCO$_2$
In low flow states such as during CPR:

↓ *blood flow* = ↓ *ETCO₂*

↑ *blood flow* = ↑ *ETCO₂*
Laboratory Studies of Capnography

ETCO₂ has been shown to be a useful indicator for CPR quality in animal models

Expired carbon dioxide: a noninvasive monitor of cardiopulmonary resuscitation.  
C V Gudipati, M H Weil, J Bisera, H G Deshmukh and E C Rackow

_Circulation_. 1988;77:234-239  
doi: 10.1161/01.CIR.77.1.234

Changes in expired end-tidal carbon dioxide during cardiopulmonary resuscitation in dogs: A prognostic guide for resuscitation efforts ☆

Karl B. Kern, MD, FACC, Arthur B. Sanders, MD, William D. Voorhees, PHD, Charles F. Babbs, MD, PHD, Willis A. Tacker, MD, PHD, Gordon A. Ewy, MD, FACC

DOI: 10.1016/0735-1097(89)90282-9
Clinical Use of Capnography in Cardiac Resuscitation

Recommended by American Heart Association 2010 Guidelines

Excerpt from the 2010 AHA Resuscitation Guidelines Part 1

Real-time monitoring and optimization of CPR quality using either mechanical parameters (e.g., monitoring of chest compression rate and depth, adequacy of chest wall relaxation, length and duration of pauses in compression and number and depth of ventilations delivered) or, when feasible, physiologic parameters (partial pressure of end-tidal CO$_2$ [P$_{ETCO_2}$], arterial pressure during the relaxation phase of chest compressions, or central venous oxygen saturation [Scvo$_2$]) are encouraged. When quantitative waveform capnography is used for adults, guidelines now include recommendations for monitoring CPR quality and detecting ROSC based on P$_{ETCO_2}$ values.

Little clinical data exist to support the use of capnography to monitor CPR quality in humans.
Proof of Concept: Physiologic CPR

Hemodynamic directed CPR improves cerebral perfusion pressure and brain tissue oxygenation\*,\**,

Stuart H. Friess\*, Robert M. Sutton\b, Benjamin French\c, Utpal Bhalala\d, Matthew R. Maltese\b, Maryam Y. Naim\b, George Bratino\v, Silvana Arciniegas Rodriguez\b, Theodore R. Weiland\b, Mia Garuccio\b, Vinay M. Nadkarni\b, Lance B. Becker\e, Robert A. Berg\b

Am J Respir Crit Care Med. First published online 16 Oct 2014 as DOI: 10.1164/rccm.201407-1343OC

Patient-Centric Blood Pressure Targeted CPR Improves Survival from Cardiac Arrest


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Hypothesis

• We hypothesized that increased rate and depth of CC will be associated in real-time with increased ETCO$_2$ during both in-hospital cardiac arrest (IHCA) and out-of-hospital cardiac arrest (OHCA)
Methods

Retrospective Multicenter Cohort Study

Data collected from 4/2006 – 5/2013

In-hospital

University of Chicago

University of Pennsylvania

Out-of-hospital

Tualatin Valley Fire & Rescue

Dallas FD
Fort Worth FD
Medstar Ambulance
Methods

Loss of pulse

QCPR recording

ETCO₂ monitoring

ROSC or end of code

Timeline of code

Epochs used for data analysis

15 sec

15 sec

15 sec
Methods: Data Analysis

Data analysis:

Mixed effect regression
  • Accounted for clustering by site and event

Model:
  • Assessed ETCO$_2$ in relation to rate, depth, ventilation rate independently
207 events excluded

77 No overlapping ETCO₂ and CPR
104 <2 minutes of ETCO₂ and CPR
26 technical reasons (corrupt files)

790 Cardiac Arrests

583 Cardiac Arrests

227 IHCA Cardiac Arrests
10304 15 sec epochs

356 OHCA Cardiac Arrests
18724 15 sec epochs

29028 15 sec epochs
## Results

<table>
<thead>
<tr>
<th>Demographics</th>
<th>n = 583</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Years ± SD</strong></td>
<td>63.7 ± 17.1</td>
</tr>
<tr>
<td><strong>Female, n (%)</strong></td>
<td>213 (37)</td>
</tr>
<tr>
<td><strong>Daytime Arrest (7a-7p)</strong></td>
<td>409 (70)</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>285 (49)</td>
</tr>
<tr>
<td>Black</td>
<td>153 (26)</td>
</tr>
<tr>
<td>Other</td>
<td>34 (6)</td>
</tr>
<tr>
<td>Unknown</td>
<td>111 (19)</td>
</tr>
<tr>
<td><strong>Initial Rhythm</strong></td>
<td></td>
</tr>
<tr>
<td>Asystole</td>
<td>170 (29)</td>
</tr>
<tr>
<td>PEA</td>
<td>209 (36)</td>
</tr>
<tr>
<td>VF/VT</td>
<td>134 (23)</td>
</tr>
<tr>
<td>Other</td>
<td>16 (3)</td>
</tr>
<tr>
<td>Unknown</td>
<td>54 (9)</td>
</tr>
<tr>
<td><strong>ROSC</strong></td>
<td>189 (32)</td>
</tr>
<tr>
<td><strong>Survival to Discharge</strong></td>
<td>40 (7)</td>
</tr>
</tbody>
</table>
Results

Rate
Median 110.3

Depth
Median 43.5

Ventilation Rate
Median 12.0

ETCO₂
Median 25.6
# Results

<table>
<thead>
<tr>
<th></th>
<th>10 mm increase in CC depth</th>
<th>10 cpm increase in CC rate</th>
<th>10 bpm increase in vent rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All</strong></td>
<td>↑ 1.4 mmHg*</td>
<td>↓ 0.5 mmHg</td>
<td>↓ 3.0 mmHg*</td>
</tr>
<tr>
<td>n= 29028</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>In-hospital</strong></td>
<td>↑ 1.7 mmHg*</td>
<td>↓ 0.5 mmHg</td>
<td>↓ 2.0 mmHg*</td>
</tr>
<tr>
<td>n= 10304</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Out-of-hospital</strong></td>
<td>↑ 1.3 mmHg*</td>
<td>↓ 0.2 mmHg</td>
<td>↓ 3.6 mmHg*</td>
</tr>
<tr>
<td>n= 18724</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.001
Regression analysis illustrating ETCO₂ in relation to chest compression depth measured at 5 fixed rates.
Regression analysis illustrating ETCO$_2$ in relation to chest compression rate measured at 5 fixed depths.
Limitations

• Retrospective study with inherent limitations

• Time synchronized drug administration not assessed (e.g. epinephrine and bicarbonate)

• Increased ventilation rate correlates with lower ETCO₂ values (recorded ventilation rate, but not volume)
Current work

- Collecting minute ventilation during CPR:
  - MRx QCPR
  - Respironics NM3 Monitor

- Mechanize exact cardiac arrest details and times
  - Epinephrine administration
  - Pauses
  - Shocks
Conclusions

• Significant correlation of deeper compressions with higher ETCO$_2$ values

• No significant correlation between ETCO$_2$ and CC rate

• Significant correlation of increased ventilation with decreased ETCO$_2$

• This work helps refine the definition of high-quality CPR, and suggests the feasibility of physiologic monitoring during CPR
Thank you!

CRS Clinical Team
## Survival

**Table 4.** Mean CC rate, CC depth, and ETCO\(_2\) among cases stratified by ROSC and survival to discharge.

<table>
<thead>
<tr>
<th></th>
<th>ROSC</th>
<th>no ROSC</th>
<th>p-value</th>
<th>survival to discharge</th>
<th>no survival to discharge</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rate (cpm)</strong></td>
<td>109.0 ± 8.4</td>
<td>110.0 ± 9.7</td>
<td>NS</td>
<td>110.0 ± 7.6</td>
<td>109.6 ± 9.4</td>
<td>NS</td>
</tr>
<tr>
<td>**Depth (mm)</td>
<td>44.5 ± 8.0</td>
<td>43.8 ± 8.5</td>
<td>NS</td>
<td>44.9 ± 7.7</td>
<td>44.0 ± 8.3</td>
<td>NS</td>
</tr>
<tr>
<td><strong>ETCO(_2) (mmHg)</strong></td>
<td>34.5 ± 4.5</td>
<td>23.1 ± 13.7</td>
<td>&lt;.001</td>
<td>38.2 ± 12.9</td>
<td>26.1 ± 15.2</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>
Clinical Implications Of Small Effect Size

- Our study aimed to look show there was a positive relationship between ETCO$_2$ and CPR Quality Metrics

-- Noise in the signal
  -- Respiratory rate/tidal volume ventilation
  -- Specific patient etiology/physiology
  -- Drug administration
  -- Others

- What can you gather clinically from this?
  -- Chest compression depth seems to matter more than chest compression rate, push hard!
Interaction between ETCO$_2$ and Ventilation Rate

- Is it representative of cardiac output or are you just blowing off CO$_2$?
  - We don’t know

- Since we know ventilation rate is a confounder:
  - We are going to need to measure other physiologic measures to assess to really understand physiology based CPR
  - Aline during arrest for CPP and compare to ETCO$_2$
Phase Shift in ETCO2 and CPR

-Assessed phase shift by 5, 10 seconds no difference in results
Time-Series VS Mixed Effect Regression

- Clinically impractical to use time series analysis

-- Mixed effects: able to account for inter and intra subject variation
  - Allows each case to follow its own trajectory
  - Allows each case to start at its own baseline and follow its own slope and doesn’t pare everything into population averages, account for more variation
  - Lose these in time-series
Sheak et al, ReSS 2014

Idris et al, Circulation 2012
Figure 2. A–C, Plots of outcomes vs. average compression depth. ROSC, return of spontaneous circulation.