Start Measuring. Start Improving. Webinar Series

Techniques and Devices for Measuring Chest Compressions

Thursday November 17, 2016
11:00am – 12:00pm Central
Presenter: Dr. Benjamin Abella, MD, MPH, FAHA

Heart.org/Resuscitation
Techniques and Devices for Measuring Chest Compressions

Benjamin Abella, MD, MPH, FAHA

Associate Professor, Department of Emergency Medicine, University of Pennsylvania

Vice Chair for Research, Department of Emergency Medicine, University of Pennsylvania

Associate Scholar, Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania

Clinical Research Director, Center for Resuscitation Science, University of Pennsylvania
CPR quality: what it is, why it matters, and practical techniques to use it

Benjamin S. Abella, MD, MPhil, FAC EP

GWTG Webinar
November 2016
Electrical recording of the heart rhythm:

**Normal rhythm:** heart is moving blood (functional "cardiac output")

**Cardiac arrest rhythm:** chaotic rhythm means no blood flow (no functional "cardiac output")

In cardiac arrest, abrupt and total loss of cardiac output

Uniformly fatal unless immediate treatment given (e.g. CPR)
Overview of cardiac arrest mortality

- % Surviving
- Time
- Hospital discharge

Arrest
CPR
Defibrillation
ROSC
Drs. Knickerbocker, Kouwenhoven, and Jude - Johns Hopkins, 1950s - studied defibrillation and chest compressions in the laboratory
The birth of modern CPR

A. Peter Safar, 1950s
B. Early symposium on CPR

1961
The “Chain of Survival”

First proposed in 1991 by the American Heart Association:

In 2015:

The key importance of prompt CPR

5th link: post-arrest therapies
Do rescue breaths matter?

CPR with Chest Compression Alone or with Rescue Breathing

Thomas D. Rea, M.D., Carol Fahrenbruch, M.S.P.H., Linda Culley, B.A., Rachael T. Donohoe, Ph.D., Cindy Hambly, E.M.T., Jennifer Innes, B.A., Megan Bloomingdale, E.M.T., Cleo Subido, Steven Romines, M.S.P.H., and Mickey S. Eisenberg, M.D., Ph.D.

Bystander contacted 9-1-1

- standard CPR (n=960)
  - 11.5%

- chest compression alone (n=981)
  - 14.4% (OR 2.9)

Survival to DC
CPR hemodynamics

Blood pressure

Time

= chest compression

Berg et al, 2001
CPR hemodynamics

Blood pressure vs. time showing chest compression events.

Berg et al, 2001
Poor survival with lowest compression fraction in OHCA.
Chest compression depth

ICCM, 2005

Survival:
100%
15%

CPR duration, min

2 inches vs 1.5 inches

CPP, mm Hg

ICCM, 2005

CPR duration, min

Survival:
100%
15%

Chest compression depth

ICCM, 2005
Chest compression depth

What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation?*

Ian G. Stiell, MD; Siobhan P. Brown; James Christenson; Sheldon Cheskes; Graham Nichol; Judy Powell; Blair Bigham; Laurie J. Morrison; Jonathan Larsen; Erik Hess; Christian Vaillancourt; Daniel P. Davis; Clifton W. Callaway; the Resuscitation Outcomes Consortium (ROC) Investigators

CCM 2012
Rate of 100-120 may be best; too slow or too fast may yield worse outcomes
Chest compression quality and outcome

Quantifying the Effect of Cardiopulmonary Resuscitation Quality on Cardiac Arrest Outcome
A Systematic Review and Meta-Analysis

Sarah K. Wallace, AB; Benjamin S. Abella, MD, MPhil; Lance B. Becker, MD

Deeper compressions
Favors survival; no max
Depth identified

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean difference in mm (95% CI)</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abella (2005 JAMA)</td>
<td>1.00 (-5.39, 7.39)</td>
<td>3.81</td>
</tr>
<tr>
<td>Babbs (2008)*</td>
<td>2.50 (-3.63, 8.63)</td>
<td>4.13</td>
</tr>
<tr>
<td>Bohn (2011)</td>
<td>1.90 (-0.01, 3.81)</td>
<td>42.43</td>
</tr>
<tr>
<td>Edelson (2006) (IHCAs)*</td>
<td>8.37 (-4.27, 21.01)</td>
<td>0.97</td>
</tr>
<tr>
<td>Edelson (2006) (OHCAs)*</td>
<td>-0.03 (-7.93, 7.87)</td>
<td>2.49</td>
</tr>
<tr>
<td>Kramer-Johansen (2006)*</td>
<td>3.30 (0.93, 5.67)</td>
<td>27.66</td>
</tr>
<tr>
<td>Stiell (2012)*</td>
<td>2.70 (-0.20, 5.60)</td>
<td>18.49</td>
</tr>
<tr>
<td>Overall (I² = 0.0%, p = 0.895)</td>
<td>2.44 (1.19, 3.69)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

NOTE: Weights are from random effects analysis
Devices currently in use

- Philips Mrx with QCPR
- Zoll R series with Real CPR help
- Physio Control Tru CPR sensor
CPR: actual resuscitation recording

- ventilations
- rhythm check
- ECG
- compressions
- ECG: v tach
- ECG: v fib
- shock given

03:10
Compression rate in actual practice

Abella et al, 2005

n=1626 segments

Number of 30 sec segments

Chest compression rate (min⁻¹)
Compression rate and outcome

Mean rate, ROSC group
90 ± 17 *

Mean rate, no ROSC group
79 ± 18 *

p=0.003

Abella et al, 2005

Compression rate and outcome

Number of 30 sec segments

Chest compression rate (min⁻¹)

Abella et al, 2005
The problem with cardiac arrest training
The military solution to training
Improving CPR quality using feedback

Figure 2. Cardiopulmonary resuscitation (CPR) quality as a percentage of time within target range. Data are given as percentage of 30-second segments during the first 5 minutes of CPR that are 15/min or less for ventilations, 38 mm or greater for compression depth, and 90/min to 120/min for compression rate. *P* < 0.001 for each parameter. RAPID indicates resuscitation with actual performance integrated debriefing.

Edelson et al, 2008
Improving IHCA survival

![Bar chart showing comparison of ROSC (return of spontaneous circulation) between baseline and RAPID cohorts.](image)

**Figure 3.** Return of spontaneous circulation (ROSC) by cohort. RAPID indicates resuscitation with actual performance integrated debriefing.

Edelson et al, 2008
CPR feedback and debriefing in OHCA

The Influence of Scenario-Based Training and Real-Time Audiovisual Feedback on Out-of-Hospital Cardiopulmonary Resuscitation Quality and Survival From Out-of-Hospital Cardiac Arrest

Bentley J. Bobrow, MD; Tyler F. Vadeboncoeur, MD; Uwe Stolz, PhD, MPH; Annemarie E. Silver, PhD; John M. Tobin, CEP; Scott A. Crawford, EMT-B; Terence K. Mason, RN; Jerome Schirmer, CEP; Gary A. Smith, MD; Daniel W. Spaite, MD

EMS version of the Edelson 2008 study

Performed using Zoll feedback defibrillators in Arizona
## CPR feedback and debriefing in OHCA

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall</th>
<th>Preperiod</th>
<th>Postperiod</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total, No. (%)</td>
<td>484 (100)</td>
<td>232 (47.9)</td>
<td>252 (52.1)</td>
</tr>
<tr>
<td>Age, median (IQR), y</td>
<td>68 (56–79)</td>
<td>69 (59–79)</td>
<td>68 (55–79)</td>
</tr>
<tr>
<td>Male sex, No. (%)</td>
<td>322 (66.5)</td>
<td>149 (64.2)</td>
<td>173 (68.7)</td>
</tr>
<tr>
<td>Witnessed arrest, No. (%)</td>
<td>192 (39.8)</td>
<td>98 (42.2)</td>
<td>94 (37.3)</td>
</tr>
<tr>
<td>Shockable rhythm on EMS arrival, No. (%)</td>
<td>150 (31.0)</td>
<td>79 (34.1)</td>
<td>71 (28.2)</td>
</tr>
<tr>
<td>Provision of bystander CPR, No. (%)</td>
<td>192 (39.7)</td>
<td>102 (44.0)</td>
<td>90 (35.7)</td>
</tr>
<tr>
<td>Location of arrest, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential</td>
<td>353 (72.9)</td>
<td>167 (72.0)</td>
<td>186 (73.8)</td>
</tr>
<tr>
<td>Medical facility</td>
<td>68 (14.1)</td>
<td>32 (13.8)</td>
<td>36 (14.3)</td>
</tr>
<tr>
<td>Public</td>
<td>63 (13.0)</td>
<td>33 (14.2)</td>
<td>30 (11.9)</td>
</tr>
<tr>
<td>EMS response interval, median (IQR), min</td>
<td>5 (4–6)</td>
<td>5 (4–6)</td>
<td>5 (4–6)</td>
</tr>
<tr>
<td>Use of TH, No. (%)</td>
<td>52 (10.7)</td>
<td>23 (9.9)</td>
<td>29 (11.5)</td>
</tr>
<tr>
<td>MICR protocol compliance (complete vs partial), No. (%)</td>
<td>375 (77.5)</td>
<td>155 (66.8)</td>
<td>220 (87.3)</td>
</tr>
<tr>
<td>Return of spontaneous circulation, No. (%)</td>
<td>113 (23.4)</td>
<td>58 (25.0)</td>
<td>55 (21.8)</td>
</tr>
<tr>
<td>Survival to hospital discharge for all rhythms, No./total (%)*</td>
<td>55/483 (11.4)</td>
<td>20/231 (8.7)</td>
<td>35/252 (13.9)</td>
</tr>
<tr>
<td>Survival to hospital discharge for witnessed arrests, shockable rhythms, No./total (%)*</td>
<td>35/93 (37.6)</td>
<td>15/57 (26.3)</td>
<td>20/36 (55.6)</td>
</tr>
<tr>
<td>Favorable functional outcome (CPC score=1 or 2) for all rhythms, No./total (%)†</td>
<td>42/481 (8.7)</td>
<td>15/230 (6.5)</td>
<td>27/251 (10.8)</td>
</tr>
<tr>
<td>Favorable functional outcome (CPC score=1 or 2) for witnessed arrests, shockable rhythms, No./total (%)†</td>
<td>27/91 (29.7)</td>
<td>11/56 (19.6)</td>
<td>16/35 (45.7)</td>
</tr>
</tbody>
</table>
Ventilation rate in actual practice

Mean ventilation rate: 30 ± 3.2

First group: 37 ± 4 → After retraining: 22 ± 3

Aufderheide et al, 2004
Pre-shock compression pauses

Pause before shock
Pre-shock pauses and outcomes

VF removed, percent

- ≤10.3 seconds (n=10): 90%
- 10.5-13.9 seconds (n=11): 64%
- 14.4-30.4 seconds (n=11): 55%
- ≥33.2 seconds (n=10): 10%

p=0.003

Edelson et al, 2006
AHA Consensus Statement

Cardiopulmonary Resuscitation Quality: Improving Cardiac Resuscitation Outcomes Both Inside and Outside the Hospital

A Consensus Statement From the American Heart Association

Endorsed by the American College of Emergency Physicians

Peter A. Meaney, MD, MPH, Chair; Bentley J. Bobrow, MD, FAHA, Co-Chair;
Mary E. Mancini, RN, PhD, NE-BC, FAHA; Jim Christenson, MD; Allan R. de Caen, MD;
Farhan Bhanji, MD, MSc, FAHA; Benjamin S. Abella, MD, MPhil, FAHA;
Monica E. Kleinman, MD; Dana P. Edelson, MD, MS, FAHA; Robert A. Berg, MD, FAHA;
Tom P. Aufderheide, MD, FAHA; Venu Menon, MD, FAHA; Marion Leary, MSN, RN;
on behalf of the CPR Quality Summit Investigators, the American Heart Association Emergency
Cardiovascular Care Committee, and the Council on Cardiopulmonary, Critical Care,
Perioperative and Resuscitation

2013
CPR “report cards” in the future?

A. Report Card: general checklist

- Was the team leader clearly identified? 
  - No
  - Intermediate
  - Yes

- Was the scene orderly and quiet? 
  - No
  - Intermediate
  - Yes

- Was the defibrillator applied quickly? 
  - No
  - Intermediate
  - Yes

- Was CPR started promptly? 
  - No
  - Intermediate
  - Yes

- Were pauses in CPR delivery minimized? 
  - No
  - Intermediate
  - Yes

- Was CPR of subjectively high quality? 
  - No
  - Intermediate
  - Yes

- Were peri-shock pauses minimized? 
  - No
  - Intermediate
  - Yes

- Was an airway secured efficiently? 
  - No
  - Intermediate
  - Yes

B. Report Card: CPR quality analysis

- Event number / date: V0131 3-9-12

- Compression fraction: 92%

- Mean compression rate: 102

- Mean compression depth (mm): 49

- Compressions without leaning: 75%

- Mean ventilation rate: 9

Comments: Great team leadership, good effort by all, but remember to MINIMIZE pauses in CPR, esp. before/after shocks.

Comments: Great rate and hands on time; remember to keep pre-shock and post-shock pauses short to improve shock success.
Cardiac arrest stories in the media

Friday, June 13, 2008

Tim Russert, TV correspondent
Known asymptomatic coronary dz
Suffered AMI $\rightarrow$ cardiac arrest

Attempted resuscitation (CPR and defibrillation) failed

Unknown CPR quality or pre-shock pause time
Cardiac arrest stories in the media

Friday, June 25, 2009

Michael Jackson died at home

Respiratory arrest from drug OD

Attempted resuscitation (CPR and defibrillation) failed

CPR performed in the bed – questionable quality, pauses in performance?
March 17, 2012

Fabrice Muamba had cardiac arrest while on UK football field

Arrest duration was over 78 minutes

Prolonged CPR and shocks - Full neurologic recovery
End-tidal CO$_2$ (ET-CO$_2$)

Advantages: non-invasive
clinically available
extensively studied

Expiration inspiration

CO$_2$

ET-CO$_2$
ET-CO2 reflects CPR quality: Is it the future of CPR monitoring?
Invasive BP monitoring for CPR

Work from our group at Penn in the swine laboratory – suggests that using blood pressure improves CPR

Patient-Centric Blood Pressure–targeted Cardiopulmonary Resuscitation Improves Survival from Cardiac Arrest

Robert M. Sutton¹, Stuart H. Friess², Maryam Y. Naim¹, Joshua W. Lampe³, George Bratino³, Theodore R. Weiland III¹, Mia Garuccio¹, Vinay M. Nadkarni¹, Lance B. Becker³, and Robert A. Berg¹

¹Department of Anesthesiology and Critical Care Medicine, The Children’s Hospital of Philadelphia, and ³Department of Emergency Medicine, The Hospital of the University of Pennsylvania, University of Pennsylvania Perelman School of Medicine, Philadelphia, Pennsylvania; and ²Department of Pediatrics, St. Louis Children’s Hospital, Washington University in St. Louis School of Medicine, St. Louis, Missouri

<table>
<thead>
<tr>
<th></th>
<th>Guideline Care (n = 10)</th>
<th>BP Care (n = 10)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any ROSC, n (%)</td>
<td>3 (33)</td>
<td>10 (100)</td>
<td>0.003</td>
</tr>
<tr>
<td>45-minute ICU survival, n (%)</td>
<td>1 (10)</td>
<td>9 (90)</td>
<td>0.001</td>
</tr>
<tr>
<td>24-hour survival, n (%)</td>
<td>0 (0)</td>
<td>8 (80)</td>
<td>0.001</td>
</tr>
<tr>
<td>Favorable neurologic outcome, n (%)</td>
<td>0 (0)</td>
<td>7 (70)</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Physiologic monitoring of CPR quality during adult cardiac arrest: A propensity-matched cohort study

Robert M. Sutton a,*, Benjamin French b, Peter A. Meaney a, Alexis A. Topjian a, Christopher S. Parshuram c, Dana P. Edelson d, Stephen Schexnayder e, Benjamin S. Abella f, Raina M. Merchant f, Melania Bembea g, Robert. A. Berg a, Vinay M. Nadkarni a, for the American Heart Association’s Get With The Guidelines-Resuscitation Investigators

Table 2
Comparison of resuscitation outcomes among adults with and without monitoring.a

<table>
<thead>
<tr>
<th>Outcome</th>
<th>With n (%)</th>
<th>Without n (%)</th>
<th>OR (CI95) b</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return of spontaneous circulation</td>
<td>2117/3032(70)</td>
<td>3973/6064(66)</td>
<td>1.22 (1.04, 1.43)</td>
<td>0.017</td>
</tr>
<tr>
<td>Survival to hospital discharge</td>
<td>527/3020(17)</td>
<td>1019/6022(17)</td>
<td>1.04 (0.91, 1.18)</td>
<td>0.57</td>
</tr>
<tr>
<td>Survival with favorable neurological outcome</td>
<td>368/2911(13)</td>
<td>757/5840(13)</td>
<td>0.97 (0.75, 1.26)</td>
<td>0.83</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval.

a Each participant with monitoring was matched to two participants without monitoring based on a propensity score that included all variables listed in Supplementary Table 1.

b Odds ratios compare the odds of an outcome between index events with vs. without monitoring, estimated from a logistic regression model with a robust variance estimator to account for within-hospital correlation.

Table 3
Comparison of resuscitation outcomes among index events with ETCO2 monitoring (n ~ 803 index events).

<table>
<thead>
<tr>
<th>Outcome</th>
<th>ETCO2 &gt; 10 mmHg n (%)</th>
<th>ETCO2 ≤ 10 mmHg n (%)</th>
<th>OR (CI95) a</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival to hospital discharge</td>
<td>125/520 (24)</td>
<td>31/282 (11)</td>
<td>2.41 (1.25, 4.30)</td>
<td>0.003</td>
</tr>
</tbody>
</table>
Devices to improve CPR quality

**Manual CPR support devices**

- Zoll AED, R series
- Philips MRx

**Mechanical CPR devices**

- Zoll Autopulse
- LUCAS
Out-of-hospital, Richmond, VA (one site)

<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>Autopulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC</td>
<td>101/499 (20.2%)</td>
<td>96/278 (34.5%)</td>
</tr>
<tr>
<td>Admitted</td>
<td>54/485 (11.1%)</td>
<td>58/277 (20.9%)</td>
</tr>
<tr>
<td>D/C</td>
<td>14/486 (2.9%)</td>
<td>27/278 (9.7%)</td>
</tr>
</tbody>
</table>

Mechanical CPR: the Richmond experience

Ong et al, 2006
**Hallström et al, 2006 (ASPIRE)**

Out-of-hospital, multicenter RCT - US, Canada

<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>Autopulse</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC</td>
<td>92/373 (24.7%)</td>
<td>104/394 (26.4%)</td>
</tr>
<tr>
<td>D/C</td>
<td>37/373 (9.9%)</td>
<td>23/394 (5.8%)</td>
</tr>
</tbody>
</table>
Manual vs. integrated automatic load-distributing band CPR with equal survival after out of hospital cardiac arrest. The randomized CIRC trial

Lars Wik, Jan-Aage Olsen, David Persse, Fritz Sterz, Michael Lozano Jr., Marc A. Brouwer, Mark Westfall, Chris M. Souders, Reinhard Malzer, Pierre M. van Grunsven, David T. Travis, Anne Whitehead, Ulrich R. Herken, E. Brooke Lerner

Table 3
Comparison of outcome by treatment arm.

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>M-CPR (n = 2132)</th>
<th>iA-CPR (n = 2099)</th>
<th>Covariate adjusted odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival to Hospital Discharge</td>
<td>233 (11.0%) (7 cases unknown)</td>
<td>196 (9.4%) (5 cases unknown)</td>
<td>0.89 (0.72–1.10)</td>
</tr>
<tr>
<td>Survival to 24 h</td>
<td>532 (25.0%) v</td>
<td>456 (21.8%) (10 cases unknown)</td>
<td>0.86 (0.74–0.998)</td>
</tr>
<tr>
<td>Sustained ROSC</td>
<td>689 (32.3%)</td>
<td>600 (28.6%)</td>
<td>0.84 (0.73–0.96)</td>
</tr>
<tr>
<td>Discharge mRS</td>
<td>(n=233)</td>
<td>(n = 196)</td>
<td>0.80 (0.47–1.37)</td>
</tr>
<tr>
<td>Score of 0–3</td>
<td>112 (48.1%)</td>
<td>87 (44.4%)</td>
<td></td>
</tr>
<tr>
<td>Score of 4–5</td>
<td>61 (26.2%)</td>
<td>50 (25.5%)</td>
<td></td>
</tr>
<tr>
<td>Unknown score</td>
<td>60 (25.8%)</td>
<td>59 (30.1%)</td>
<td></td>
</tr>
</tbody>
</table>
Mechanical CPR: trial of LUCAS device

Mechanical versus manual chest compression for out-of-hospital cardiac arrest (PARAMEDIC): a pragmatic, cluster randomised controlled trial

Gavin D Perkins, Ranjit Lal, Tom Quinn, Charles D Deakin, Matthew W Cooke, Jessica Horton, Sarah E Lamb, Anne-Marie Slowther, Malcolm Woillard, Andy Carson, Mike Smyth, Richard Whitfield, Amanda Williams, Helen Pocock, John J M Black, John Wright, Kyee Han, Simon Gates, PARAMEDIC trial collaborators*
Mechanical CPR: possible applications

- EMS / long transport times
- Medical flight programs

- Emergency Department or ICU environment

- Cardiac catheterization lab
Mechanical CPR devices

Mechanical Chest Compression Devices

2015 (Updated): The evidence does not demonstrate a benefit with the use of mechanical piston devices for chest compressions versus manual chest compressions in patients with cardiac arrest. Manual chest compressions remain the standard of care for the treatment of cardiac arrest. However, such a device may be a reasonable alternative to conventional CPR in specific settings where the delivery of high-quality manual compressions may be challenging or dangerous for the provider (eg, limited rescuers available, prolonged CPR, CPR during hypothermic cardiac arrest, CPR in a moving ambulance, CPR in the angiography suite, CPR during preparation for ECPR).

2010 (Old): Mechanical piston devices may be considered for use by properly trained personnel in specific settings for the treatment of adult cardiac arrest in circumstances (eg,
M-CPR and E-CPR as bridge to cath
1. Cardiac arrest is not hopeless!

2. CPR quality has big impact

3. Minimize ventilations

4. Maximize chest compression rate and depth

5. Consider CPR feedback tools and code debriefing
Chest compression quality and outcome

Research team staff

David Buckler
Magda Wernovsky
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Shaun McGovem
Dan Ikeda
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Gail Delfin
Kelsey Sheak
Marisa Cinousis

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Learn more at [heart.org/resuscitation](http://heart.org/resuscitation)