New Frontiers in Resuscitation Science

Daniel Davis, MD
UCSD Center for Resuscitation Science
Key Concepts

- Compressions
- Ventilations
- Pressors
- PetCO2
- Post-resuscitative care
1. Optimal Compressions
The Primary Directive

Chest compressions should be performed from the moment of arrest until return of spontaneous circulation is assured.
Prime the Pump!

Kern (2002) *Circulation*
Stay on the chest!

* Adjusted for: age, gender, bystander CPR, public location, response time, compression rate

Christenson (2009) *Circulation*
Compression Interruptions

- Initiating compressions
- Rhythm analysis
- Shock sequence
- Pulse check
- Intubation
- Vascular access
ECG Filtration
Return of Spontaneous Circulation

Heart Rate (BPM) & PetCO2 (mmHg)

Electrical (HR)

Mechanical (PetCO2)
Deeper Compressions

Good Recoil

Aufderheide (2005) *Resuscitation*
# Rate vs Depth

<table>
<thead>
<tr>
<th>Depth</th>
<th>Rate</th>
<th>0 to 80 (N=65)</th>
<th>81 to 120 (N=478)</th>
<th>121+ (N=122)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;38 mm</td>
<td></td>
<td>49%</td>
<td>44%</td>
<td>69%</td>
</tr>
<tr>
<td>38-51 mm</td>
<td></td>
<td>28%</td>
<td>44%</td>
<td>30%</td>
</tr>
<tr>
<td>&gt;51 mm</td>
<td></td>
<td>23%</td>
<td>12%</td>
<td>2%</td>
</tr>
</tbody>
</table>

CPR Process
Code # 79265 (11/28/12)
Code Leader: Brendan Daly, MD
Recorded CPR time: 5 minutes
Type of arrest: VF/VT

<table>
<thead>
<tr>
<th>Minute</th>
<th>Chest Compression Fraction (goal &gt;90%)</th>
<th>Average Compression Rate (goal 100)</th>
<th>Average Compression Depth (inches) (goal 2-4 inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
<td>118</td>
<td>3.02</td>
</tr>
<tr>
<td>2</td>
<td>73%</td>
<td>107</td>
<td>2.98</td>
</tr>
<tr>
<td>3</td>
<td>82%</td>
<td>115</td>
<td>3.10</td>
</tr>
<tr>
<td>4</td>
<td>85%</td>
<td>121</td>
<td>2.85</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Defibrillations: 1
Pre-shock pause (goal <3 seconds) 14 seconds
Post-shock pause (goal < 6 seconds) 3 seconds
Use of End Tidal Carbon Dioxide: Yes
Other comments: Good compression rate and depth, great use of EtCO2.

Summary: (selected strips below)
## Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest compression fraction</td>
<td>91%</td>
</tr>
<tr>
<td>Compression rate</td>
<td>123/min</td>
</tr>
<tr>
<td>Compression depth</td>
<td>2.6 inches</td>
</tr>
<tr>
<td>Pre-shock pause</td>
<td>2.6 sec</td>
</tr>
<tr>
<td>Post-shock pause</td>
<td>3.6 sec</td>
</tr>
<tr>
<td>Perfusion check</td>
<td>4.3 sec</td>
</tr>
<tr>
<td>Ventilation rate</td>
<td>9.7/min</td>
</tr>
<tr>
<td>PetCO2</td>
<td>15.3 mmHg</td>
</tr>
</tbody>
</table>
What if we’re wrong?
Experimental paper

Ischemic postconditioning at the initiation of cardiopulmonary resuscitation facilitates functional cardiac and cerebral recovery after prolonged untreated ventricular fibrillation

Nicolas Segal\textsuperscript{a}, Timothy Matsuura\textsuperscript{a}, Emily Caldwell\textsuperscript{a}, Mohammad Sarraf\textsuperscript{a}, Scott McKnite\textsuperscript{a}, Menekhem Zviman\textsuperscript{b}, Tom P. Aufderheide\textsuperscript{c}, Henry R. Halperin\textsuperscript{b}, Keith G. Lurie\textsuperscript{a,d}, Demetris Yannopoulos\textsuperscript{a,*}

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\textsuperscript{c} Department of Emergency Medicine at the Medical College of Wisconsin, United States
\textsuperscript{d} Department of Emergency Medicine at the University of Minnesota, United States
15 minutes of untreated VF

Aortic pressure tracing (mmHg)

Pause 20sec
Pause 20sec
Pause 20sec
Pause 20sec
CPR 40sec
CPR 20sec
CPR 20sec
CPR 20sec
CPR
ROSC

0.5 mg of Epinephrine

ROSC
Cerebral Performance Category Score at 24 and 48 hours.

SCPR

SCPR + PC

§ p < 0.0001

* p = 0.0034

CPC

24 hours

48 hours
2. Controlled ventilation
Prime the Pump!

Continuous Chest Compressions with Synchronous Ventilations (10:1)
3. Pressor Therapy
Pressors

Mader (2008) *Resuscitation*
Prehospital Epinephrine Use and Survival Among Patients With Out-of-Hospital Cardiac Arrest

Akihito Hagihara, DMSc, MPH
Manabu Hasegawa, MD
Takeru Abe, MA
Takashi Nagaoka, MD
Yoshifumi Wakata, MD
Shogo Miyazaki, PhD

Epinephrine is widely used in cardiopulmonary resuscitation (CPR) for patients with out-of-hospital cardiac arrest (OHCA). However, its effectiveness in CPR has not been established. Epinephrine is associated with increased myocardial oxygen consumption and ventricular arrhythmias during the period after resuscitation. Concern has been raised regarding increased myocardial dysfunction and dis-

Hagihara (2012) JAMA
Vasopressin?
Fluids?
Potential adverse effects of volume loading on perfusion of vital organs during closed-chest resuscitation

Roy V. Ditchey, M.D., and JoAnn Lindenfeld, M.D.

ABSTRACT To determine whether expansion of blood volume improves vital organ perfusion pressures and blood flow during closed-chest cardiopulmonary resuscitation in dogs, we recorded intracranial and high-fidelity ascending aortic and right atrial pressures and measured total and regional blood flow with radioactive microspheres during cardiopulmonary resuscitation before and after rapid infusion of 1 liter of saline or dextran in 12 animals. Volume loading increased total forward blood flow from 327.1 ± 50.9 to 692.7 ± 105.9 ml/min (p < .01). However, blood flow to the cerebral hemispheres, cerebellum, brainstem, and ventricular myocardium all decreased significantly. For example, blood flow to the left cerebral hemisphere fell from 16.5 ± 2.4 to 5.5 ± 1.7 ml/min/100 g (p < .001), while left ventricular myocardial blood flow fell from 12.0 ± 3.1 to 4.1 ± 0.8 ml/min/100 g (p < .05). These changes in critical regional flow were accompanied by disproportionate increases in right atrial and intracranial pressures (relative to aortic pressure), which reduced the average pressure differences generated across the coronary and cerebral circulations from 11.0 ± 2.5 to 3.7 ± 1.3 mm Hg (p < .01) and from 16.1 ± 2.3 to 10.5 ± 1.5 mm Hg (p < .01), respectively. The overall rise in forward flow was associated with a marked increase in extracranial, brachiocephalic blood flow. These findings suggest that large increments in blood volume can reduce vital organ perfusion during cardiopulmonary resuscitation despite an increase in total forward blood flow.

**Myocardial Blood Flow (ml/min/100gm)**

- Control CPR 1
- Control CPR 2
- Volume CPR 1
- Volume CPR 2

* *p < .05 vs. both controls

- Left Ventricle: NS
- Right Ventricle: NS

- * indicates significance.
Prehospital Lactated Ringer’s Solution Treatment and Survival in Out-of-Hospital Cardiac Arrest: A Prospective Cohort Analysis

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1 Kyushu University Graduate School of Medicine, Department of Health Services Management and Policy, Fukuoka, Japan, 2 Ambulance Service Planning Division, Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications, Tokyo, Japan, 3 Kyushu University Hospital, Department of Emergency and Critical Care Center, Fukuoka, Japan

Abstract

Background: No studies have evaluated whether administering intravenous lactated Ringer’s (LR) solution to patients with out-of-hospital cardiac arrest (OHCA) improves their outcomes, to our knowledge. Therefore, we examined the association between prehospital use of LR solution and patients’ return of spontaneous circulation (ROSC), 1-month survival, and neurological or physical outcomes at 1 month after the event.

Methods and Findings: We conducted a prospective, non-randomized, observational study using national data of all patients with OHCA from 2005 through 2009 in Japan. We performed a propensity analysis and examined the association between prehospital use of LR solution and short- and long-term survival. The study patients were ≥18 years of age, had an OHCA before arrival of EMS personnel, were treated by EMS personnel, and were then transported to hospitals. A total of 531,854 patients with OHCA met the inclusion criteria. Among propensity-matched patients, compared with those who did not receive pre-hospital intravenous fluids, prehospital use of LR solution was associated with an increased likelihood of ROSC before hospital arrival (odds ratio [OR] adjusted for all covariates [95% CI] = 1.239 [1.146–1.339] [p<0.001]), but with a reduced likelihood of 1-month survival with minimal neurological or physical impairment (cerebral performance category 1 or 2, OR adjusted for all covariates [95% CI] = 0.764 [0.589–0.992] [p = 0.04]; and overall performance category 1 or 2, OR adjusted for all covariates [95% CI] = 0.746 [0.573–0.971] [p = 0.03]). There was no association between prehospital use of LR solution and 1-month survival (OR adjusted for all covariates [95% CI] = 0.960 [0.854–1.078]).

Conclusion: In Japanese patients experiencing OHCA, the prehospital use of LR solution was independently associated with a decreased likelihood of a good functional outcome 1 month after the event, but with an increased likelihood of ROSC before hospital arrival. Prehospital use of LR solution was not associated with 1-month survival. Further study is necessary to verify these findings.

Please see later in the article for the Editors’ Summary.


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Competing Interests: The article’s contents are solely the responsibility of the authors and do not necessarily represent the official views of the Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications, or Kyushu University. The authors have declared that no competing interests exist.

Abbreviations: AED, automated external defibrillator; CPC, Cerebral Performance Category; EMS, emergency medical service; LR, lactated Ringer’s; OHCA, out-of-hospital cardiac arrest; OPC, Overall Performance Category; OR, odds ratio; ROSC, return of spontaneous circulation; VF, ventricular fibrillation

* E-mail: hagihara@hspm.med.kyushu-u.ac.jp
4. PetCO2 in resuscitation
Lung Perfusion in Shock

PaCO₂ 40 mmHg

PetCO₂ 37 mmHg

PetCO₂ 29 mmHg

PetCO₂ 21 mmHg
PetCO2 Monitoring

- EtCO2 = 35 mmHg
- Resp Rate = 18
- Successful Defibrillation
- CPR
- Return of Spontaneous Circulation
PetCO2 Associations

- Initial PetCO2 $\alpha$ ROSC
- Pre-shock PetCO2 $\alpha$ ROSC for VF
- Rise in PetCO2 $\alpha$ ROSC
- Initial PetCO2 $\alpha$ arrest etiology
- Compression depth/patient wt $\alpha$ PetCO2
5. Post-resuscitation care
Hyperventilation: Three Flavors

EtCO2

Ventilation

Vents (breaths/min)
Cerebral Perfusion During Shock

mL/100 gm/min

P = .004 v 12

P = .004 v 12
Ventilation in Resuscitation

- RS1 Interim: 1.84 (1.01, 3.36)
- RS1 Final: 1.80 (1.10, 3.00)
- SD Prehosp: 2.20 (1.50, 3.20)
- Seattle Prehosp: 1.80 (1.01, 3.00)
Rapid, Shallow Breaths?

95% CI for the regression estimate
Intrathoracic Pressure
Evidence for Hypothermia?
Hypothermia vs. Normothermia?

Hypothermia After Cardiac Arrest Study Group (2002) *NEJM*
When should we cool?
Post-Arrest Hypothermia

- **HACA**
  - No cooling: 36%
  - 33°C: 53%

- **Bernard**
  - No cooling: 26%
  - 33°C: 49%

- **TTM**
  - 36°C: 52%
  - 33°C: 50%
How should we cool?
How should we cool?
2014 UCSD ART/PART ARREST ALGORITHM

Initial Assessment
IF ARREST¹, THEN START COMPRESSIONS²

Defibrillate³ ASAP (may repeat as needed two or more times)

Not VF/VT OR Unmonitored

Compressions²
Ventilations⁴
Pressors
- Vasopressin (ADULT)⁵
- Epinephrine⁵

Monitor
- Shockable rhythm or signs of perfusion (ECG, ETCO₂, SpO₂)

Reversible cause of arrest?⁶

CPR

May alternate every 3 min; epinephrine for suspected ACS (VF); vasopressin for sepsis/hemorrhage

VF/VT
HR >40 (adults)
HR >60 (younger children) AND ETCO₂ >20

No perfusion

Defibrillate
- Administer pressor (if not recently given)
- 2 min CPR → Shock³ → Immediate CPR
- If persists/recurs, amiodarone⁶

Perfusion check (<10 sec)
- Pulse check
- Sustained ETCO₂ without compressions
- ECG–SpO₂ concordance

Post-Arrest Care
- Maintain ventilations (ETCO₂ ~35 mmHg)
- Adjust FIO₂ to keep SpO₂ 95-98%
- Hemodynamic support/fluids
- Consider hypothermia, PCI

¹Unresponsive + apneic/gasping (+/- pulseless) OR VF/asystole OR HR<30 (adults), HR<60 (younger children) OR sudden ↓ HR/ETCO₂

²Continuous compressions; 2” inches adult, at least 1/3 AP diameter ped, 80-120/min, full recoil

³120J-150J-200J adult, 2J/kg-4J/kg-4J/kg ped; minimal pause in compressions before/after shocks

⁴Synchronous (10:1) with continuous compressions (no pause); two rescuers; “two-thumbs-up” mask hold; consider OPA/NPA/airway pressure; intubate (min compression pause) when possible

⁵Vasopressin (40U adult); epinephrine (1mg adult; 0.01mg/kg [0.1mg/kg ET] ped); amiodarone (300mg-150mg adult; 5mg/kg-5mg/kg-5mg/kg ped); atropine (1mg adult; 0.02mg/kg, min 0.5mg ped)

⁶Hypovolemia (IVF/blood); hyper-K⁺ (NaHCO₃, CaCl₂); hypoglycemia (D50); acidosis (NaHCO₃); PE (TPA); tension pneumothorax (needle); vagal (atropine); hypothermia (warming); recurrent VF (PCI)
Arrest Survival

Survival-to-Discharge (%)

Current U.S. Benchmark
Conclusions

- The opportunity is staggering
- Compressions
- Technology
- Post-resuscitative care
Advanced Resuscitation Training

People should not die before they are done living.