Impact of Pre-hospital and Emergency Care on Cardiac Arrest Outcomes

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Co-Chairman, International Liaison Committee on Resuscitation 2007-2010

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The Children’s Hospital of Philadelphia, Philadelphia PA, USA
Potential Conflicts of Interest

• Employment: University of Pennsylvania

• Research Grants:
  – NIH/ NICHD (Cardiac Arrest, Glucose Control)
  – AHRQ (Simulation Education)
  – Laerdal Foundation (Simulation and Resuscitation)
  – Medical Education Technology, Inc (Simulation)

• Science Advisory Board (Volunteer)
  – AHA National Registry of CPR
  – Pediatric ALI and Sepsis Investigators
  – World Federation of Pediatric and ICU Societies
PRESENT PREHOSPITAL Cardiac arrest outcomes

- 50% No Restoration of Spontaneous Circulation
- 25% Die In Hospital
- 25% Leave Hospital
- 15% Good Outcome
- 10% Brain Damage
Clinical Trials

Registries and CQI

Single Center
Selected Specific
100% x 80% = 20%

Multi-center Trial
Efficacy

Patient outcome

Multi-center Application
Effectiveness

General Practice
Efficiency

Patient outcome

Clinical Trials and Registries and CQI are connected through a patient outcome and various specific outcomes at different stages, leading to a final efficiency of 20%.
Pediatric Cardiac Arrest Process and Outcomes

Patient Factors

System Factors

Event Factors

Data

Patient

Interventions

Outcomes

Data

Quality of Life

Favorable Neurologic Survival

Short term Survival

Discharge Survival

ROSC

System/Quality

Texts:
- Patient
- Interventions
- Outcomes
- Patient Factors
- System Factors
- Event Factors
- Technique
- Drugs
- Devices
- Education
- System/Quality
- Quality of Life
- Short term Survival
- Discharge Survival
- Favorable Neurologic Survival
Three Phases of Adult VF Cardiac Arrest

Electrical Phase (Early Defibrillation Critical)

Hemodynamic Phase (Perfusion Critical)

Metabolic Phase (Newer Modalities Needed)

Becker et al. JAMA 2002;288:303
**CHAIN OF SURVIVAL**

- No CPR
- Delayed defibrillation

- Early CPR
- Delayed defibrillation

- Early CPR
- Early defibrillation

- Early CPR
- Very early defibrillation

Defibrillation

- 0-2% Survival
- 2-8% Survival
- 20% Survival
- 30% Survival

minutes
2 4 6 8 10
Quality CPR Improves Short Term Survival

Kramer-Johansen et. al., Resuscitation 2006
Quality CPR Improves Shock Success

![Bar chart showing CPR quality and shock success rates](chart.png)
### Pre-existing conditions are different in Child vs Adult

<table>
<thead>
<tr>
<th>Condition</th>
<th>CHILD</th>
<th>ADULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory Insufficiency</td>
<td>58% *</td>
<td>40%</td>
</tr>
<tr>
<td>Shock</td>
<td>36% *</td>
<td>27%</td>
</tr>
<tr>
<td>MI</td>
<td>2%</td>
<td>35% *</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1%</td>
<td>28% *</td>
</tr>
<tr>
<td>Renal Failure</td>
<td>12%</td>
<td>31% *</td>
</tr>
</tbody>
</table>

Nadkarni et al. JAMA 2006
Event Characteristics are different in Child vs Adult

<table>
<thead>
<tr>
<th></th>
<th>CHILD</th>
<th>ADULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location in ICU</td>
<td>65% *</td>
<td>45%</td>
</tr>
<tr>
<td>Witnessed or monitored</td>
<td>95% *</td>
<td>88%</td>
</tr>
<tr>
<td>Witnessed &amp; monitored</td>
<td>83% *</td>
<td>66%</td>
</tr>
<tr>
<td>Mechanical Ventilation</td>
<td>57% *</td>
<td>26%</td>
</tr>
<tr>
<td>Vasopressors</td>
<td>38% *</td>
<td>27%</td>
</tr>
<tr>
<td>Arterial Catheter</td>
<td>29% *</td>
<td>8%</td>
</tr>
<tr>
<td>Duration of CPR</td>
<td>25 [12,45]</td>
<td>18 [10,29]</td>
</tr>
</tbody>
</table>

Nadkarni et al. JAMA 2006
### Initial VF/VT rhythm is good

<table>
<thead>
<tr>
<th>Event</th>
<th>Initial VF/VT vs Sub VF/VT</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC (&gt; 20 min)</td>
<td>70% vs. 35%</td>
</tr>
<tr>
<td></td>
<td>OR 2.8 (1.5 - 5.4)</td>
</tr>
<tr>
<td>Survival to Hospital Discharge</td>
<td>35% vs. 11%</td>
</tr>
<tr>
<td></td>
<td>OR 2.9 (1.2 - 5.8)</td>
</tr>
<tr>
<td>Survival with Favorable Neurologic Outcome</td>
<td>33% vs. 8%</td>
</tr>
<tr>
<td></td>
<td>OR 2.6 (1.2 - 5.8)</td>
</tr>
</tbody>
</table>

Samson et al. NEJM 2006
### Subsequent VF/VT rhythm is bad

<table>
<thead>
<tr>
<th></th>
<th>No VF/VT vs Sub VF/VT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ROSC (&gt; 20 min)</strong></td>
<td>51% vs 35%</td>
</tr>
<tr>
<td></td>
<td>OR 2.1 (1.3 - 3.4)</td>
</tr>
<tr>
<td><strong>Survival to Hospital Discharge</strong></td>
<td>27% vs 11%</td>
</tr>
<tr>
<td></td>
<td>OR 3.8 (1.8 - 7.6)</td>
</tr>
<tr>
<td><strong>Survival with Favorable Neurologic Outcome</strong></td>
<td>24% vs 8%</td>
</tr>
<tr>
<td></td>
<td>OR 3.8 (1.9 - 7.7)</td>
</tr>
</tbody>
</table>

Samson et al. NEJM 2006
Pediatric Cardiac Arrest: Facts

- **Out-of-hospital Pediatric Cardiac Arrest:**
  - Respiratory Etiology
  - Rarely witnessed, monitored or shockable initial rhythms

- **In-Hospital Pediatric Cardiac Arrest**
  - Combined Respiratory/Cardiac Etiology
  - Complex, critically ill patients
  - Commonly witnessed, monitored and common shockable rhythms (14-27%)

Donoghue et al. AEM 2005

Nadkarni et al. JAMA 2006
Pulseless Arrest

VF/VT
- Single Shock
- Epinephrine
- Single Shock
- Anti-arrhythmic?

CPR
- Push Hard
- Push Fast
- Minimize Interruptions
- Complete Release
- Breathe Slow
- Seek reversible causes*

Not VF/VT
- Epinephrine
- CPR
Rapid Recognition

Call 9-11

Rapid Response Team

Post- Arrest stabilization

Pre-Arrest

Cardiac Arrest

No Flow

Low Flow

Low, Normal or High Flow

CPR

PROTECTION

PRESERVATION

RESUSCITATION

RESUSCITATION / REGENERATION

Cardiac Arrest

CPR

Temperature control

Blood pressure

Glucose

Ventilation (CO2)

Goal Directed Care

Push hard, Push Fast

Minimize interruption

Full chest recoil

Assist ventilation?

Vasopressors?

Defibrillate if VF Waveform?

Dose?

1 vs 3?

PRESERVATION

RESUSCITATION

RESUSCITATION / REGENERATION
The “Bow Tie” Concept

- Pre-Arrest Recognition and Intervention
- Cardiac Arrest
- Neonatal Resuscitation Program
- ACLS
- PALS
- Post Resuscitation Outcomes
What is Fact vs what is Fiction?

World’s first successful cryonics awakening!

CORPSE FROZEN FOR 97 YEARS BROUGHT BACK TO LIFE!

PROVIDENCE, R.I. — Doctors have revived a corpse that was frozen solid since 1902 — and restored the woman to perfect health!

That’s the word from sources in a government research facility who report that the woman, 55 at the time she died of pneumonia, was successfully thawed and treated with antibiotics.

The woman lived in this city during the Victorian era. She was an eccentric who paid to have the body placed outside the city limits. No one knew who she was or where she came from.

By BEATRICE DEXTER
Weekly World News

Advances could restore her to life. Refrigeration had been perfected since a few years after its invention in 1834.

"Her name was Clara Valston and she was a well-known resident of Rhode Island in the late 1800s," said one U.S. government scientist who asked that we not use his name.

"When she was revived, she has suffered no ill-effects at all from her 97 years as a frozen corpse."

The secret project involving Mrs. Valston has attracted a number of top scientists including a nationally known neurologist, a biochemist and two pulmonary specialists.

Since the woman regained her health, she has been undergoing intensive interviews with historians and psychologists.

The CIA is believed to have hidden Mrs. Valston in a rural area in the Northeast, where she is from a long state of suspended participation," the government scientist said. "There’s more..."
Fact: Interventions that seem to work in animals do NOT always translate to improved clinical outcomes...
What is the relevant endpoint for resuscitation outcome?
How do we change?

<table>
<thead>
<tr>
<th>Basis for Decision</th>
<th>Measure</th>
<th>Device</th>
<th>Unit of measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EVIDENCE</strong></td>
<td>Randomized Controlled Trial</td>
<td>Meta-analysis</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td>Eloquence</td>
<td>Smoothness of Tongue</td>
<td>Keynote speech</td>
<td>&quot;Kissoon&quot; unit</td>
</tr>
<tr>
<td>Vehemence</td>
<td>Loudness of voice</td>
<td>Audiometer</td>
<td>Decibels</td>
</tr>
<tr>
<td>Confidence</td>
<td>Bravado</td>
<td>Sweat test</td>
<td>No sweat</td>
</tr>
</tbody>
</table>
Challenges: Etiology based approach

- Trauma
- Overdose
- Submersion
- Airway Obstruction
- Newborn
- Sudden VF
- Prolonged VF
- Acute Coronary Syndromes
Prehospital vs. In-Hospital

Pediatric First Documented Cardiac Arrest Rhythm

Nadkarni et al. JAMA 2006 and Young et al. Pediatrics 2004
AHA National Registry of CPR:
Shockable Rhythms in Hospitalized Children < 18 years

- All Events with CC: 7%
- Pulseless CA Events: 15%
- Anytime during event: 25%

Samson et al NEJM 2006
Nadkarni et al JAMA 2006
Quality of Cardiopulmonary Resuscitation During In-Hospital Cardiac Arrest

Benjamin S. Abella, MD, MPhil
Jason P. Alvarado, BA
Helge Myklebust, BEng
Dana P. Edelson, MD
Anne Barry, RN, MBA
Nicholas O’Hearn, RN, MSN
Terry L. Vanden Hoek, MD
Lance B. Becker, MD

Context  The survival benefit of well-performed cardiopulmonary resuscitation (CPR) is well-documented, but little objective data exist regarding actual CPR quality during cardiac arrest. Recent studies have challenged the notion that CPR is uniformly performed according to established international guidelines.

Objectives  To measure multiple parameters of in-hospital CPR quality and to determine compliance with published American Heart Association and international guidelines.

Design and Setting  A prospective observational study of 67 patients who experienced in-hospital cardiac arrest at the University of Chicago Hospitals, Chicago, Ill, between December 11, 2002, and April 5, 2004. Using a monitor/defibrillator with added data-capture capability, the quality of CPR, as defined by the International Liaison Committee on Resuscitation guidelines, was assessed.

In-hospital:
CPR was inconsistent and often did not meet published guideline recommendations... Too few compressions, too many ventilations, too many pauses.
What we SAY we do...

What we REALLY do...!
Maximal O2 Delivery

Lay Rescuer

Maximize flow and oxygen delivery

Babbs, Kern 2002
Mathematical Modeling
Compression : Ventilation Ratios
Children

- “Optimal CPR” (best systemic oxygen delivery)
- Optimal C-V ratio for:

<table>
<thead>
<tr>
<th>Weight (kg)</th>
<th>Lay Rescuers (CPR Rate)</th>
<th>Professional (CPR Rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>~ 12:2</td>
<td>~ 12:2</td>
</tr>
<tr>
<td>20</td>
<td>~ 24:2</td>
<td>~ 15:2</td>
</tr>
<tr>
<td>40</td>
<td>~ 30:2</td>
<td>~ 20:2</td>
</tr>
</tbody>
</table>

Babbs C, Nadkarni V Resuscitation 2004
Drugs in Cardiac Arrest

Vasopressors
- Adrenergic
  - Adrenaline
  - Methoxamine
  - Phenylephrine
  - Norepinephrine
  - Dopamine
  - Isoproterenol
  - Orciprenaline
  - Dobutamine
- Non-Adrenergic
  - Angiotensin II
  - Endothelin-1
  - Vasopressin

Antiarrhythmics
- Lidocaine
- Amiodarone
- Theophylline
- Atropine

Buffer
- NaHCO₃
- TRIS
- Na₂CO₃
- Carbicarb
- Tribonate

Others
- Others

10 Most Frequently Administered Medications from the CHOP pediatric code cart

<table>
<thead>
<tr>
<th>Medication</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epinephrine</td>
<td>184</td>
</tr>
<tr>
<td>Sodium Bicarbonate</td>
<td>127</td>
</tr>
<tr>
<td>Calcium Gluconate</td>
<td>121</td>
</tr>
<tr>
<td>Atropine</td>
<td>99</td>
</tr>
<tr>
<td>0.9% NaCl</td>
<td>87</td>
</tr>
<tr>
<td>Tromethamine</td>
<td>61</td>
</tr>
<tr>
<td>Vecuronium</td>
<td>47</td>
</tr>
<tr>
<td>Pancuronium</td>
<td>41</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>39</td>
</tr>
<tr>
<td>Midazolam</td>
<td>37</td>
</tr>
</tbody>
</table>

Improving the post cardiac arrest link in the chain of survival
Post-resuscitation care
Infant undergoing Selective Hypothermia with a cooling cap

Courtesy: Dr. David Durand, Children’s Hospital Oakland
Infant undergoing Total Body Cooling with a Cooling Blanket
Mechanical Support – during or After CPR

<table>
<thead>
<tr>
<th>Pre-Load</th>
<th>Contractility</th>
<th>Afterload</th>
<th>Heart rate and rhythm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check the plumbing</td>
<td>Check the function</td>
<td>Check the circuits</td>
<td>Check the rate and rhythm</td>
</tr>
<tr>
<td>Fluid bolus?</td>
<td>R/o tamponade?</td>
<td>Shunt fxn?</td>
<td>Too slow?</td>
</tr>
<tr>
<td>Diuretics?</td>
<td></td>
<td>Pressors? Dilators?</td>
<td>Atrial kick?</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pacer fxn?</td>
</tr>
</tbody>
</table>
ECMO for Refractory Cardiac Arrest

In-Hosp Cardiac Arrest

ECMO team notified

CPR + ALS x 10 minutes

ECMO circuit clear prime

CPR + ALS

Cannulate Neck V-A

ECMO:

Induced Hypothermia
Controlled blood flow titrated to SvO2
Standard Sedation/Monitoring
Normalize glucose, Blood Pressure, pCO2
Follow markers of Organ injury/function

Anti-Coagulate?

??Cold Perfusate

Endpoint?
Brain

- Cerebral perfusion
- Sedation
- Control of seizures
- Temperature control
- Glucose control
## Gap between Training and Implementation

<table>
<thead>
<tr>
<th>Challenges Noted During Simulations</th>
<th>% of Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child Weight Estimates</td>
<td>34%</td>
</tr>
<tr>
<td>IO preparation</td>
<td>69%</td>
</tr>
<tr>
<td>IV Fluid Bolus</td>
<td>89%</td>
</tr>
<tr>
<td>Order Glucose bolus</td>
<td>97%</td>
</tr>
</tbody>
</table>

Difficulty with 25/44 (57%) C-Spine Stabilization Tasks


Simulation of C-Spine Stabilization in 35 North Carolina Emergency Departments
Implementing the guidelines: training and practice
Team Training…building competence to Excellence!

“Just-in-time….Just-in-place”
Improving CPR Techniques

- Mechanisms to evaluate and “see-through” artifacts to allow near continuous chest compressions
Defibrillator Pads (mV)
Ventilations and Feedback
Chest Compression Depth (mm)
Acceleration (G)
Impedance (Ohm)
Force (grams)

Still Going...
Time: 25:00

What happened here?
# Chest Compression (CC) Quantitative Data: n=10

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Time</td>
<td>134.32 min</td>
</tr>
<tr>
<td>Total CC Delivered</td>
<td>13,136</td>
</tr>
<tr>
<td>Chest Compression Rate</td>
<td>113 ± 13.4 CC/min</td>
</tr>
<tr>
<td>Chest Compression Count</td>
<td>98 ± 7.1 CC/min</td>
</tr>
<tr>
<td>No Flow Time</td>
<td>10.33 ± 0.9 min</td>
</tr>
<tr>
<td>No Flow Fraction</td>
<td>7.7 ± 5.4 %</td>
</tr>
<tr>
<td>Percent Incomplete Release</td>
<td>13.6 ± 9.5 %</td>
</tr>
<tr>
<td>Percent Adequate Depth</td>
<td>86.8 ± 16.1 %</td>
</tr>
</tbody>
</table>
**Chest Compression (CC)**

**Quantitative Data: n=10**

<table>
<thead>
<tr>
<th></th>
<th>PEDI ATRI C</th>
<th>In-Hospital Adult*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest Compression Rate</td>
<td>7.7 %</td>
<td>24 %</td>
</tr>
<tr>
<td>Chest Compression Count</td>
<td>86.8 %</td>
<td>62 %</td>
</tr>
<tr>
<td>Percent Adequate Depth</td>
<td>86.8 %</td>
<td>38 %</td>
</tr>
<tr>
<td>No Flow Fraction</td>
<td>7.7 %</td>
<td>48 %</td>
</tr>
</tbody>
</table>

*Abella, JAMA 2005*  
*Wik, JAMA 2005*
Summary/Conclusions

For Out of Hospital Cardiac Arrest:
- Push hard, push fast, complete release, Minimize interruptions, Do NOT over-ventilate

For In-Hospital Cardiac Arrest:
- Etiology specific response will improve outcome
  - Respond before arrest (Rapid Response)
  - Emphasize Quality of CPR
  - Use adjuncts and monitor effects/feedback

Advanced techniques have merit but are not proven
Cardiac Arrest And Resuscitation

Oxidative Stress with Free Radical Production And Endothelial Damage

AXONAL & DENDRITIC INJURY

VASCULAR DYSREGULATION

Free Radicals

↑ CBV

INFLAMMATION & REGENERATION

Brain Injury

↑ TISSUE OSMOLAR LOAD

Mitochondrial Failure

K⁺ EAA NO Ca²⁺ O₂⁻ AA

NEURO-TOXICITY

NECROSIS

APOPTOSIS

ASTROCYTE SWELLING

VASOGENIC EDEMA
Guideline Principles

- Early Detection and Intervention
  - Universal monitoring
  - METS
  - Automated Directive Feedback (Prompts)

- Improved Circulation
  - Less interruption (C:V ratio, Fewer shocks)
  - Less Ventilation (titrated to blood flow and microcirculation)
  - Adjuncts (circumferential, thoracic pump)

- Real-time Corrective feedback based upon the patient’s metabolic status
On the Horizon

- Metabolic therapies
  - Therapeutic hypothermia
  - Chemical hibernation
- Post-resuscitative care
  - Blood Pressure, Temperature, Glucose, Ventilation, Thrombolysis, myocardial support, rapid mechanical support
- Better Predictors
  - Imaging, Neurophysiology and biomarkers
- Genomics and proteomics
  - Hibernation / Regeneration / Transplantation
Training and Preparedness

• Home therapies
  – Smart AEDs in the home, video links, “smoke alarm and fire extinguisher” mentality
• Short and simple training
  – School, Work, Driver’s License
• Just-in time support and training
  – 111, flashes, physiologic feedback, incorporation into everyday life (ATM, stadium, groceries)
**Rapid Recognition**

Call 9-1-1

**METs**

---

**Pre-Arrest**

Cardiac Arrest

**CPR**

Post-Arrest stabilization

---

**No Flow**

No Flow

**Low Flow**

Low Flow

**Low, Normal or High Flow**

Low, Normal or High Flow

---

**PROTECTION**

- Rapid Recognition
  - Call 9-1-1
  - METs

**PRESERVATION**

- Prompt CPR
  - Defibrillate if VF
    - Waveform?
    - Dose?
    - 1 vs 3?

**RESUSCITATION**

- Push hard, Push Fast
  - Minimize interruption
  - Full recoil
  - Assist ventilation?
    - Vasopressors?
    - Cooling?

**RESUSCITATION / REGENERATION**

- Temperature control
- Blood pressure
- Glucose
- Ventilation (CO2)
  - Goal Directed Care
We are going to have to look deeper to discover evidence that lies beneath the surface...

Next planned revision of AHA Guidelines: 2010
Rapid Recognition
Call 9-1-1

Pre-Arrest
Cardiac Arrest

No Flow
Low Flow
Low, Normal or High Flow

• PROTECTION
  • Rapid Recognition
  • Call 9-1-1
  • METs

• PRESERVATION
  • Prompt CPR; Defibrillate if VF
    • Waveform?
    • Dose?
    • 1 vs 3?

• RESUSCITATION
  • Push hard, Push Fast
    • Minimize interruption
    • Full recoil
    • Assist ventilation?
      • Vasopressors?
      • Cooling?

• RESUSCITATION / REGENERATION
  • Temperature control
  • Blood pressure
  • Glucose
  • Ventilation (CO2)
  • Goal Directed Care

Post-Arrest stabilization

CPR
<table>
<thead>
<tr>
<th>Quality of CPR</th>
<th>CPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push Hard</td>
<td></td>
</tr>
<tr>
<td>Push Fast</td>
<td></td>
</tr>
<tr>
<td>Allow full chest recoil</td>
<td></td>
</tr>
<tr>
<td>Minimize Interruptions</td>
<td></td>
</tr>
<tr>
<td>Don’t Overventilate</td>
<td></td>
</tr>
</tbody>
</table>
Virtual-PICU/ PALISI (Zaritsky)

NRCPR (Berg/Nadkarni)

pHeart (Berg/Nadkarni)

Canada HYPCAP (Hutchison)

PECARN (Moler)

NICHD PCCRN Network (Dean/Willson)

Local Databases

International Databases
Europe
Australia
New Zealand
USA
Latin America
Asia

Virtual-PICU/ PALISI
(Zaritsky)