Treatment of Cardiac Arrest

January 28, 2016

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University of Minnesota
Cardiac Electrophysiologist, St. Cloud hospital
Disclosure

- Dr. Lurie is co-inventor of the impedance threshold device (ITD)(ResQPOD) and active compression decompression (ACD) CPR (CardioPump)

- Dr. Lurie is a consultant for Zoll Medical Corporation.
<7% Survival with Good Brain Function
>30% Survival with Good Brain Function
Take Heart America
Sudden Cardiac Arrest Survival Initiative

A SYSTEMS-BASED APPROACH TO SUDDEN CARDIAC ARREST SURVIVAL

Bystanders
—provide the critical immediate response:
- Learn CPR and how to use an AED
- Recognize sudden cardiac arrest
- Send someone to call 911 and get an AED

First Responders
—assume responsibility for continued life-saving through:
- Rapid response
- High performance CPR
- Use of impedance threshold device (ITD)
- Rapid AED placement

Hospital Staff at a Cardiac Arrest Center
—get the patient to neurologically intact survival through:
- Therapeutic hypothermia
- 24/7 Revascularization
- Electrophysiology
- ICD implantation
- Tracking outcomes

EMS Personnel
—provide additional life-saving measures through:
- High performance CPR
- Advanced airway management
- Use of impedance threshold device (ITD)
- Intra-osseous drug delivery
- Automated CPR devices (optional)

651-403-5636
www.TakeHeartAmerica.org
Transformative Technologies

Bystander CPR Education

AED

ICD

Lay Public

First Responder

Hospital

EMS

Angiography

Automated CPR

IO Meds

Therapeutic Hypothermia
The MN Resuscitation Consortium connects bystander, prehospital and hospital initiatives to improve survival from sudden cardiac arrest (SCA).
## 2013 Cardiac Arrest Registry to Enhance Survival Data

<table>
<thead>
<tr>
<th>Data</th>
<th>Minnesota N=2319</th>
<th>National N=54807</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-hospital Outcome (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronounced in the Field</td>
<td>1005 (43.3)</td>
<td>13847 (25.3)</td>
</tr>
<tr>
<td>Pronounced in ED</td>
<td>167 (7.2)</td>
<td>9756 (17.8)</td>
</tr>
<tr>
<td>Ongoing Resuscitation in ED</td>
<td>1147 (49.5)</td>
<td>31202 (56.9)</td>
</tr>
<tr>
<td>Overall Survival (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall Survival to Hospital Admission</td>
<td>718 (31.0)</td>
<td>14676 (26.8)</td>
</tr>
<tr>
<td>Overall Survival to Hospital Discharge</td>
<td>336 (11.5)</td>
<td>5621 (10.3)</td>
</tr>
<tr>
<td>With Good or Moderate Cerebral Performance</td>
<td>302 (13.0)</td>
<td>433 (7.9)</td>
</tr>
<tr>
<td>Missing hospital outcome</td>
<td>6</td>
<td>462</td>
</tr>
<tr>
<td>Utstein Survival (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Witnessed by bystander and found in shockable rhythm</td>
<td>39.9%</td>
<td>31.5%</td>
</tr>
<tr>
<td>Utstein Bystander Survival (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Witnessed by bystander, found in shockable rhythm, and received some bystander intervention (CPR by bystander and/or AED applied by bystander)</td>
<td>46.6%</td>
<td>36.1%</td>
</tr>
</tbody>
</table>

Minnesota has the highest survival rates with good brain function.
Continuous Quality Improvement Leads to Excellent Outcomes

1. Better Perfusion
2. Reperfusion Injury Protection
3. Bundle of Care
Perfusion Today Depends on Conventional CPR

- Conventional is the cornerstone of resuscitation care; usually first option
- Conventional CPR provides 15-30% normal blood flow to the heart and brain
- Inadequate cardiac and cerebral perfusion contributes to the high mortality rates

Conventional CPR remains the cornerstone of resuscitation care
Ways to Improve Perfusion
Index Case
1987

Saved by a Household Plunger

San Francisco General Hospital
ACD CPR Device Components

- Metronome
- Force Gauge
- Handle
- Suction Cup
Compression Phase
Standard CPR (S-CPR) vs. ACD+ITD

**Chest Compressions**
- Increase in intrathoracic pressure
- Cause forward blood flow
- Force respiratory gases from lungs
  - Minimal expiratory resistance from ResQPOD
Decompression Phase

S-CPR vs. ACD+ITD

S- CPR – Passive Recoil

- Minimal change in intrathoracic pressure
- Small ↑ circulation

ACD+ITD – Active Recoil

- ↓↓ intrathoracic pressure
- Preload increased → ↑↑ cardiac output
- ICP lowered → ↑↑ cerebral perfusion
Better Perfusion
ACD + ITD
Blood Flow to Heart and Brain
Porcine V-Fib Model

ACD+ITD work synergistically to achieve desired effect

ACD+ITD CPR Mechanisms of Action

- Lowers intrathoracic pressure
- Limits inflow of air to lungs between positive pressure breaths
- Enhances venous return to right heart
- Lowers ICP
- Increases cerebral and coronary perfusion and circulation
- Reduces pulmonary vascular resistance?
ResQTrial: 2 CPR Methods

Conventional CPR  versus  ACD CPR + ITD (ResQ CPR)
# One Year Survival

<table>
<thead>
<tr>
<th></th>
<th>Conventional CPR</th>
<th>ACD+ITD</th>
<th>Relative Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cardiac Etiology</strong> (n=1655)</td>
<td>6.0%  (48/794)</td>
<td>9.0%  (74/822)</td>
<td>49%</td>
</tr>
<tr>
<td><strong>All Patients</strong> (n=2470)</td>
<td>5.8%  (68/1171)</td>
<td>7.8%  (96/1233)</td>
<td>34%</td>
</tr>
</tbody>
</table>

**First Medical Device Approved by FDA to Increase Survival after Cardiac Arrest**

Aufderheide et al, Lancet 2011  Frascone et al, Resuscitation 2013
Ways to Further Improve Perfusion
Head Flat, Up or Down?

In cardiac arrest, elevation of the head with CPR technologies that enhance circulation compared with S-CPR reduce cerebral venous pressure, lower ICP, and improve outcomes.
A Different Angle?
Supine 0° CPR

30° Head down CPR

Change of position

(CPR rate 100/min)
Supine 0° CPR  30° Head up CPR

Ao
ICP
CerPP

Change of position (CPR rate 100/min)
Inherent Limitation

Chest compressions increase arterial and venous pressures simultaneously, delivering a bidirectional high pressure compression wave to the brain with every compression.
Head-Up CPR: Effect of Angle on Mean Aortic and Intracranial Pressure

Aortic Pressure

$\text{CPR angle (°)}$

$\text{Pressure (mmHg)}$

$\text{p}=0.017$

Intracranial Pressure

$\text{CPR angle (°)}$

$\text{Pressure (mmHg)}$

$\text{p}<0.001$

CPR angle relationship with mean Aortic Pressure. $p$ value is reported for linear trend.

CPR angle relationship with mean Intracranial Pressure. $p$ value is reported for linear trend.

Debaty et al. Resuscitation, 2015
Head-Up CPR: Is the ITD Needed?

The ITD is needed to optimize Head up CPR

n=10. CPR angle relationship with Coronary Perfusion Pressure (CPP) and Cerebral Perfusion Pressure (CerPP). *p<0.05 compared to 0°. **p<0.05 compared to 30° Lucas Only
Brain Blood Flow Depends on Head Position

Brain blood flow is highest with elevation of the head.
A Simple Change in Position

ACD+ITD and Conventional CPR

Untreated VF 8 minutes
Conventional CPR flat - 2 minutes
Randomize between CPR flat vs head and shoulders up for 20 minutes
Cerebral Pressure Pressures

- ACD+ITD Head Up (n=8)
- ACD+ITD Flat (n=8)
- S-CPR Head Up (n=7)
- S-CPR Flat (n=7)

Graph showing cerebral pressure changes over time with different CPR techniques and positions.
Conclusions re: Head Up CPR

1. A potential breakthrough in understanding how to save the brain during CPR.
2. Head up CPR with the ITD enhances cerebral circulation by increasing blood flow to the brain and lowering resistance to blood flow within the brain.
3. Further research is needed.
Better Perfusion to and in the Cath Lab and Beyond
Current and Future Ways to Improve Brain Flow

1. ACD+ITD (ResQcPR)
2. Head up CPR
3. Ongoing automated CPR
4. ECMO as a bridge
Advances in Defibrillation and PEA

1. Shock with ongoing CPR
2. VF characterization (AMSA) to determine when to defibrillate
3. Compressions timed with an ECG signal
Reperfusion Injury Protection
MECHANISMS OF DISEASE

Myocardial Reperfusion Injury

Derek M. Yellon, D.Sc., and Derek J. Hausenloy, Ph.D.

CORONARY HEART DISEASE IS THE LEADING CAUSE OF DEATH WORLDWIDE, and 3.8 million men and 3.4 million women die of the disease each year. After an acute myocardial infarction, early and successful myocardial reperfusion with the use of thrombolytic therapy or primary percutaneous coronary intervention (PCI) is the most effective strategy for reducing the size of a myocardial infarct and improving the clinical outcome. The process of restoring blood flow to the ischemic myocardium, however, can induce injury. This phenomenon, termed myocardial reperfusion injury, can paradoxically reduce the beneficial effects of myocardial reperfusion.

From the Hatter Cardiovascular Institute, University College London Hospital and Medical School, London. Address reprint requests to Dr. Yellon at the Hatter Cardiovascular Institute, University College London Hospital and Medical School, 67 Chenes Mews, London WC1E 6HX, United Kingdom, or at hatter-institute@ucl.ac.uk.

Copyright © 2007 Massachusetts Medical Society.
Figure 3. New Cardioprotective Strategies for Reducing Lethal Reperfusion Injury.

For patients with an acute myocardial infarction, ischemic postconditioning or pharmacologic agents that activate the reperfusion injury salvage kinase (RISK) pathway or inhibit the opening of the mitochondrial permeability transition pore (PTP), or a multitargeted pharmacologic approach before or during the immediate onset of myocardial reperfusion, may attenuate lethal reperfusion injury and reduce the final myocardial infarct size.
Plugging the Holes with P-188

Synthetic surfactants such as poloxamer P188 has been shown in other ischemic models to reduce reperfusion injury.
Reperfusion Injury Protection Strategies

- 3 intentional 20 pauses at the start of ACD+ITD CPR – A Better BLS?
  Stay with 30:2?
- Sodium Nitroprusside + ACD+ITD CPR
- P-188 in combination with #1 and #2
- Cyclosporin A
- Anesthetics including sevoflurane
ResQCPR, ‘Intentional Stutter’, Sevoflurane, P188, Defibrillation & Post-ROSC Hypothermia for 4 hours

100% ROSC with >50% normal neurological function after 48 hours

Bartos et al, 2015 Resuscitation
A Better Bundle of Care
Starts with High Quality CPR...
What is High Quality CPR?
The Inspiration
Blood Pressure during Conventional CPR +/- ITD

A Clinical Study in Milwaukee, WI

* p<0.05

BP after 14 Minutes of ITD Use

n = 22

No Silver Bullet for Sudden Cardiac Arrest

Improved circulation is not enough
Quality of CPR is Essential
A Systems-based approach is key
CPR Quality Affects Outcomes
Ventilation Strategies

Excessive Ventilation can be DEADLY
Death by Hyperventilation

Ventilation rate: 47/min
2 vs 10: Effect on Brain Oxygen Tension

Brain $O_2$ Tension (mmHg)

- Resp Rate 2/min
- Resp Rate 10/min

Baseline

CPR

Lurie et al - Resp Care 2008
BLS Compression: Ventilation

Options:

1) continuous chest compressions with no ventilation
2) continuous chest compression with 1 breath/10 compressions
3) 30:2
Effect of No Ventilation

Normal Ventilation (Inflated Lungs)

No Ventilation (Deflated lungs)
Chest Compression & Release

Aufderheide et al
Resuscitation 2005
Translational Research – from animals to humans

Treatment of Out-of-Hospital Cardiac Arrest with High Quality CPR and the ITD

Aufderheide et al Crit Care Med 2008

Proceedings

From laboratory science to six emergency medical services systems: New understanding of the physiology of cardiopulmonary resuscitation increases survival rates after cardiac arrest

Tom P. Aufderheide, MD; Carly Alexander, BS; Charles Lick, MD; Brent Myers, MD; Laurie Romig, MD; Levon Vartanian, MD; Joseph Stothert, MD, PhD; Scott McKnife, BS; Tim Matsaura, BA; Demetris Yannopoulos, MD; Keith Lurie, MD

Objectives: The purpose of this study is to: 1) describe a newly discovered mechanism of blood flow to the brain during cardiopulmonary resuscitation using the impedance threshold device in a piglet model of cardiac arrest, and 2) describe the survival benefits in humans of applying all of the highly recommended changes in the 2005 guidelines related to increasing circulation during cardiopulmonary resuscitation, including use of the impedance threshold device, from six emergency medical services systems in the United States.

Design: An animal study was performed in which each piglet served as its own control. Historical controls were used for the human studies.


Interventions: Piglets (10-12 kg) were treated with an active (n = 9) or sham (n = 9) impedance threshold device for 6 mins of ventricular fibrillation. Humans were treated with cardiopulmonary resuscitation per the American Heart Association 2005 guidelines and the Impedance threshold device.

Measurements and Main Results: Animals: The primary endpoint in the piglet study was cardiac blood flow which increased from 56 ml/min without an impedance threshold device to 81 ml/min (p = 0.017) with impedance threshold device use. Airway pressures during the chest recoil phase decreased from -0.46 mm Hg to -2.56 mm Hg (p = 0.0006) with the active impedance threshold device. Intracranial pressure decreased more rapidly and to a greater degree during the decompression phase of cardiopulmonary resuscitation with the active impedance threshold device. Humans: Conglomerate quality assurance data were analyzed from six emergency medical services systems in the United States serving a population of ~3 million people. There were 1200 patients treated for cardiac arrest after implementation of the 2005 American Heart Association guidelines, including impedance threshold device use, and 1750 patients in the control group during the year before implementation. Demographics were similar between the two groups.

Conclusions: Use of the impedance threshold device in piglets increased cardiac blood flow, and coronary and cerebral perfusion pressures and reduced intracranial pressure during the decompression phase of cardiopulmonary resuscitation at a faster rate than controls, resulting in a longer duration of time when intracranial pressures are at their nadir. Patients in six emergency medical services systems treated with the impedance threshold device together with the renewed emphasis on more compressions, fewer ventilations, and complete chest wall recoil had a nearly 60% increase in survival rates after out-of-hospital cardiac arrest compared with historical controls. (Crit Care Med 2006;34[Suppl]:S87-584)

Keywords: cardiac arrest, sudden death; Impedance threshold device; cerebral perfusion pressure; intracranial pressure; CPR

It has been nearly a half century since closed chest cardiopulmonary resuscitation (CPR), also known as standard CPR, was first described (1). Although this technique has helped to save hundreds and thousands of people worldwide, cardiac output during CPR remains less than 20% of baseline (2, 3). Even when applied correctly, nine of every ten patients who suffer a cardiac arrest and receive standard CPR never survive an out-of-hospital cardiac arrest in most cities (4-6). These dismal survival rates prompted a reassessment of the basic physiology of CPR beginning in the mid-1990s. As a result, there have been a number of important breakthroughs in the science of resuscitation (7-32). Many of these breakthroughs were incorporated into the Ameri-
## Outcome Results from Improved BLS and ALS, including ITD Use

**Aufderheide et al. Heart Rhythm 2010**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention</th>
<th>P-value</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ROSC</strong></td>
<td>30.4% (535/1757)</td>
<td>34.1% (586/1719)</td>
<td>0.022</td>
<td>1.18 (1.022, 1.366)</td>
</tr>
<tr>
<td><strong>Hospital Discharge</strong></td>
<td>9.7% (170/1757)</td>
<td>12.6% (216/1719)</td>
<td>0.007</td>
<td>1.34 (1.078, 1.671)</td>
</tr>
<tr>
<td><strong>HD (VF)</strong></td>
<td>19.0% (85/447)</td>
<td>31.1% (128/412)</td>
<td>&lt;0.001</td>
<td>1.91 (1.384, 2.667)</td>
</tr>
<tr>
<td><strong>CPC 1 or 2</strong></td>
<td>31.4% (11/35)</td>
<td>55.2% (32/58)</td>
<td>0.033</td>
<td>2.68 (1.027, 7.213)</td>
</tr>
</tbody>
</table>

**Survival with good brain function significantly improved with high quality CPR and use of ITD**
Implementing the 2005 AHA Guidelines and Use of the ITD Improves Hospital Discharge Rates after In-Hospital Cardiac Arrest

<table>
<thead>
<tr>
<th>Hospital Discharge</th>
<th>Control</th>
<th>Intervention</th>
<th>P-value</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V-Fib</td>
<td>31.6% (18/57)</td>
<td>43.8% (21/48)</td>
<td>0.0228</td>
<td>1.68 (0.70, 4.04)</td>
</tr>
<tr>
<td>PEA</td>
<td>14.4% (14/97)</td>
<td>29.7% (27/91)</td>
<td>0.014</td>
<td>2.50 (1.15, 5.58)</td>
</tr>
<tr>
<td>Asystole</td>
<td>11.5% (10/87)</td>
<td>20.9% (23/110)</td>
<td>0.087</td>
<td>2.04 (0.86, 5.09)</td>
</tr>
<tr>
<td>Overall</td>
<td>17.4% (42/241)</td>
<td>35.3% (71/249)</td>
<td>&lt;0.001</td>
<td>2.59 (1.63, 4.13)</td>
</tr>
</tbody>
</table>
Results: Of 8718 patients included in the analysis, 4345 were randomly assigned to treatment with a sham ITD and 4373 to treatment with an active device. A total of 260 patients (6.0%) in the sham-ITD group and 254 patients (5.8%) in the active-ITD group met the primary outcome (P=0.71).

Conclusions:
Use of the ITD did not significantly improve survival with satisfactory function among patients with out-of-hospital cardiac arrest receiving standard CPR.

CPR Quality - Device Interactions
Variable Quality of Conventional CPR

Wide variations in practice even in some of the best EMS systems (data from NIH-funded Resuscitation Outcomes Consortium - ROC)

Variable compression depth and rate limit blood flow and worsens outcomes

Variations in CPR quality strongly linked to outcomes
Survival to Hospital Discharge with good neurologic function by Compression Rate (all rhythms)

Yannopoulos et al, Circulation 2015

Survival to Hospital Discharge with MRS≤3 (%) | N = 6198

<table>
<thead>
<tr>
<th>Chest Compression Rate (CC/min)</th>
<th>Sham ITD</th>
<th>Active ITD</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;90</td>
<td>19/341</td>
<td>17/310</td>
</tr>
<tr>
<td>90-99</td>
<td>34/606</td>
<td>32/561</td>
</tr>
<tr>
<td>100-109</td>
<td>47/812</td>
<td>*</td>
</tr>
<tr>
<td>110-119</td>
<td>39/618</td>
<td>32/691</td>
</tr>
<tr>
<td>120-129</td>
<td>25/397</td>
<td>26/376</td>
</tr>
<tr>
<td>&gt;129</td>
<td>24/347</td>
<td>19/306</td>
</tr>
</tbody>
</table>

* p = 0.02

Survival with Good Brain Function Improved by ITD and High Quality CPR
Importance of the Correct Rate and Depth for Improving Survival with Good Brain Function (ROC PRIMED)

Survival with MRS≤3 at rate x depth/Survivors with MRS≤3 (Sham)

Survival with MRS≤3 at rate x depth/Survivors with MRS≤3 (Active)
Outcomes from ROC PRIMED: Subjects who received Quality CPR (rate 80-120/minute; depth 4-6 cm; fraction ≥50%)

Survival to hospital discharge with MRS≤3 (%)

- **Sham ITD**
  - All patients: 37/854
  - Witnessed arrest: 25/421

- **Active ITD**
  - All patients: 61/875
  - Witnessed arrest: 50/419

Yannopoulos et al  Resuscitation 2015

\( p = 0.02 \)

\( p < 0.01 \)
High Quality CPR

- Essential for saving lives
- To be performed well, rate and depth monitoring and feedback are needed
- Devices such as the ITD need high quality CPR to work
- Training and feedback to rescue personnel is essential
Pit Crew Concept

Pit Crew CPR

Pit Crew CPR
Use the card on every arrest!
Importance of Following Protocol During Cardiac Arrest

Survival to Hospital Discharge (%)

- Protocol Not Followed: 6.7% (n=419)
- Protocol Followed: 18.1% (n=570)

OR (95% CI) 3.1 (2.02, 4.82)  P<0.001

Lick et al, 2013
How Long Should We Perform CPR?
68 minutes with Automated CPR + ITD
Automated CPR Devices

Autopulse

LUCAS

Provides High Quality CPR
Flying Blind
Need

- Physiological monitor to guide CPR and post-ROSC care
- Responsive to changes in BP/circulation/brain activity
- Works despite potential for motion artifact
Potential Non-Invasive Monitors

- ETCO2
- BP cuff
- BIS
- Cardiovascular Reserve Index
- Somatic Evoked Response
- NIRS/Reflectance
THE USE OF HYPOTHERMIA AFTER CARDIAC ARREST

DONALD W. BENSON, M.D.
G. RAINLEY WILLIAMS, JR., M.D.
FRANK O. SPENCER, M.D.
ADOLPH J. YATES, M.D.

Baltimore, Maryland
What about Prehospital Cooling?
Who should we cool?

Everyone who is unconscious upon arrival to the ED after OHCA and or after in-hospital cardiac arrest
When to pull the plug?

Redefining the limits of life...
Awakening after cardiac arrest and post resuscitation hypothermia: Are we pulling the plug too early?☆

Barbara Gold a,*, Laura Puertas e, Scott P. Davis b, Anja Metzger e, Demetris Yannopoulos d, Dana A. Oakes b, Charles J. Lick c, Debbie L. Gillquist c, Susie Y. Osaki Holm c, John D. Olsen b, Sandeep Jain b, Keith G. Lurie b, c, d, e

a Department of Anesthesia, University of Minnesota, United States
b Department of Medicine, St. Cloud Hospital, United States
c Take Heart Minnesota, United States
d Department of Internal Medicine, University of Minnesota, United States
e Department of Emergency Medicine at Hennepin County Medical Center, Minneapolis, MN, United States
Findings: 25% of all survivors are comatose 48 hours after rewarming but wake up eventually, some take as long as 2 weeks.

Patients with VF, witnessed arrest, bystander CPR, and prolonged time from 911 to profession EMS have a good prognosis.
Compliance!
Systems Approach to Cardiac Arrest in Alameda County, CA

Cardiac Arrest Survival

% Survival

<table>
<thead>
<tr>
<th>Year</th>
<th>Survival Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>10%</td>
</tr>
<tr>
<td>2006</td>
<td>16%</td>
</tr>
<tr>
<td>2007</td>
<td>13%</td>
</tr>
<tr>
<td>2008</td>
<td>28%</td>
</tr>
<tr>
<td>2009</td>
<td>28%</td>
</tr>
<tr>
<td>2010</td>
<td>32%</td>
</tr>
</tbody>
</table>

Enhancements for Prehospital Cardiac Arrest Resuscitation

## Compliance is a Challenge

<table>
<thead>
<tr>
<th></th>
<th>Full Bundle (ITD, automated CPR, and TH)</th>
<th>No Bundle (No ITD, no automated CPR, no TH)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Survival to Hospital Discharge</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All rhythms</td>
<td>37.8% (34/90)</td>
<td>12.1% (132/1090)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VF</td>
<td>62.5% (20/32)</td>
<td>29.1% (60/206)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Non-VF</td>
<td>24.1% (14/58)</td>
<td>8.1% (72/884)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Survival to Hospital Discharge with CPC≤2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All rhythms</td>
<td>25.3% (21/83)</td>
<td>6.9% (72/1051)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VF</td>
<td>51.7% (15/29)</td>
<td>23.4% (46/197)</td>
<td>0.004</td>
</tr>
<tr>
<td>Non-VF</td>
<td>11.1% (6/54)</td>
<td>3.0% (26/854)</td>
<td>0.054</td>
</tr>
</tbody>
</table>

Only 10% of patients were treated with the full bundle.
Survival after Out-of-Hospital Cardiac Arrest (All Rhythms) Today and Tomorrow

Neurologically-Intact Survival

Possible Within Next 5 Years

Today

Interventions

0%
10%
20%
30%
40%
50%

Automated CPR - Optimal Perfusion and Head up in Systems-Based Approach + Reperfusion Injury Protection

Automated CPR - Optimal Perfusion and Head up in Systems-Based Approach

Automated Optimal Perfusion in Systems-Based Approach

Improved Perfusion in Systems-Based Approach

ITD + High Quality CPR

US Average: CARES 2012
Continuous Quality Improvement: A CPR Roadmap
<table>
<thead>
<tr>
<th>Care Location</th>
<th>Lay Rescuer</th>
<th>First Responder</th>
<th>ALS</th>
<th>Post ROSC and No ROSC Transport</th>
<th>In-Hospital</th>
<th>Post Discharge</th>
</tr>
</thead>
</table>

Cardiac Arrest CQI Roadmap
<table>
<thead>
<tr>
<th>Care Location</th>
<th>Lay Rescuer</th>
<th>First Responder</th>
<th>ALS</th>
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<th>In-Hospital</th>
<th>Post Discharge</th>
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</thead>
<tbody>
<tr>
<td>Care Provided</td>
<td>▪Rural, Suburban, Urban CPR ▪Defibrillate</td>
<td>▪High Quality CPR ▪Defibrillate</td>
<td>▪High Quality CPR ▪Airway ▪Defibrillation ▪Monitoring ▪Drugs (IV access) ▪Process Data</td>
<td>▪ALS care ▪Safe for Pt and EMS ▪Protect against brain injury</td>
<td>▪TH ▪ICU ▪PCI ▪EP ▪Outcome Data</td>
<td>Data/Outcomes, survivor support</td>
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</table>
### Cardiac Arrest CQI Roadmap

<table>
<thead>
<tr>
<th>Care Location</th>
<th>Lay Rescuer</th>
<th>First Responder</th>
<th>ALS</th>
<th>Post ROSC and No ROSC Transport</th>
<th>In-Hospital</th>
<th>Post Discharge</th>
</tr>
</thead>
</table>
| Care Provided | Rural, Suburban, Urban CPR  
Defibrillate | High Quality CPR  
Defibrillate | High Quality CPR  
Airway  
Defibrillation  
Monitoring  
Drugs (IV access)  
Process Data | ALS care  
Safe for Pt and EMS  
Protect against brain injury | TH  
ICU  
PCI  
EP  
Outcome Data | Data/Outcomes, survivor support |
| QI Needed | AHA CPR  
Dispatcher CPR  
DNR status  
AED locations  
SCA alert | Optimize circulation  
CPR feedback  
Optimize shocks  
Minimize reperfusion injury  
Medical director feedback | Optimize circulation  
CPR feedback  
Optimize shocks  
Minimize reperfusion injury  
Optimize drugs and drug delivery  
Monitor circulation  
Rhythm management  
Medical director feedback | Prepare for rearrest  
more CPR  
Transport safe CPR  
activate cath lab  
Start TH  
Optimize cerebral circulation | Optimize hemodynamics  
Minimize brain injury  
Rapid assessment of coronary anatomy and revascularize  
Optimize rhythm management | Need hospital outcomes,  
Establish support groups  
Provide EMS teams feedback  
Celebrate saves  
Publicize save rates |
<table>
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<tr>
<th>Care Location</th>
<th>Lay Rescuer</th>
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How Do We Get There?
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<td>High Quality CPR, Defibrillate</td>
<td>High Quality CPR, Airway, Defibrillation, Monitoring, Drugs (IV access), Process Data</td>
<td>ALS care, Safe for Pt and EMS, Protect against brain injury</td>
<td>TH, ICU</td>
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<td>QI Needed</td>
<td>AHA CPR, Dispatcher CPR, DNR status, AED locations, SCA alert</td>
<td>Optimize circulation, CPR feedback, Optimize shocks, Minimize reperfusion injury, Medical director feedback, CPR feedback</td>
<td>Optimize circulation, CPR feedback, Optimize shocks, Minimize reperfusion injury, Optimize drug delivery, Medical director feedback, CPR feedback</td>
<td>Optimize hemodynamics, Minimize brain injury, Rapid assessment of coronary anatomy and revascularize, Optimize rhythm management</td>
<td>Need hospital outcomes, Establish support groups, Provide EMS teams feedback, Celebrate saves, Publicize save rates</td>
</tr>
<tr>
<td>Ways to achieve QI</td>
<td>CPR feedback tools, Dispatch instruction, 30:2, Widespread availability of CPR feedback tools, Optimal airway, CPR before shock, Raise Head</td>
<td>Automated CPR available, Track VS and ETCO2, Start TH, Raise Head, Titrate to MAP, ECMO, Active IPR, Cath in &lt;2 hr for VF, Cath others rapidly, Cool rapidly to 33°C, rewarm slowly, ICU care, EP routinely, Allow time to wake up, Ongoing CPR to the cath lab, IABP, ECMO, Nitroprusside</td>
<td>Automated CPR available, Track VS and ETCO2, Start TH, Raise Head, Titrate to MAP, ECMO, Active IPR, Cath in &lt;2 hr for VF, Cath others rapidly, Cool rapidly to 33°C, rewarm slowly, ICU care, EP routinely, Allow time to wake up, Ongoing CPR to the cath lab, IABP, ECMO, Nitroprusside</td>
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</table>
Thank you