The History and Science Behind Resuscitation

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Disclosures

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- R01 HL108926-03 (PI)
- 1R43HL110517-01A1
- R43HL115937-01
- R43 HL097479-01.
Overview

- The Discovery of CPR
- Bystander CPR
- Defibrillation
- Public Access Defibrillation
- Prehospital 12-lead ECGs
- Professional Rescuer CPR
- Resuscitation Centers
Cardiac resuscitation after cardiac arrest or ventricular fibrillation has been limited by the need for open thoracotomy and direct application of external cardiac compressions. This has been done only by trained medical personnel. However, the development of effective measures of exterior compressions of the heart not only in the chest but also adequate thoracotomy has opened the way for many patients. The use of this technique on 20 patients has given an overall permanent survival rate of 70%. Anyone anywhere can now initiate cardiac resuscitative procedures. All that is needed are two hands.

CLOSED-CHEST CARDIAC MASSAGE

W. B. Kouwenhoven, Dr. Ing., James R. Jude, M.D., and G. Guy Knickerbocker, M.S.E., Baltimore

The use of this technique on 20 patients has given an overall permanent survival rate of 70%. Anyone anywhere can now initiate cardiac resuscitative procedures. All that is needed are two hands.

Courtesy Depart. of Surgery
Johns Hopkins Univ. Hosp.

UHS/CMS MHW 9/82
A New Approach to Cardiac Resuscitation

JAMES R. JUDE, M.D., W. B. KOUWENHOVEN, DR. ING.,
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From the Department of Surgery, The Johns Hopkins University School of Medicine
and Hospital, Baltimore 5, Maryland

Fig. 1. Placement of the hands in application of external cardiac massage. Note that pressure is transferred to the lower sternum through the heel of the hand only.

num vertically downward with a thrusting motion. Pressure was transmitted through the heel of the hand only—none with the fingers. Compression of the heart forces blood into the systemic and pulmonary circulation (Fig. 2A). With complete relaxation of pressure the thoracic cage expands and the heart refills (Fig. 2B). The optimum rate of compression appeared to be about 60 to 80 times per minute. The chest of the unconscious adult was found to be remarkably flexible and depression of the sternum of four to five centimeters easily accomplished although the use of body weight of the operator might be necessary. To perform resuscitation during surgery it was not found necessary to undrape a supine patient. Administration of massage without becoming contaminated was usually possible.

Artificial respiration was given simultaneously with external cardiac massage. In the majority of these patients it was by face mask or intubation of the trachea. Its application was always made to assure the integrity of the first part of the oxygenation system: adequate ventilation of the lungs.

An electrocardiogram was obtained as soon as possible. If cardiac action had not yet returned it provided evidence of the type and progress of arrest. Ventricular fibrillation was treated by external defibrillation. Repetitive countershocks frequently were necessary.

Drugs were administered as necessary. Almost universally a vasopressor was given

Fig. 2. A. Pressure exerted on the lower one-third of the sternum compresses the heart and forces blood into the systemic and pulmonary systems. B. Relaxation of pressure allows the chest to expand and venous blood returns to both sides of the heart.
Bystander CPR

- AHA Scientific Statement to Reduce Barriers to Bystander CPR (Circulation 2008)
  - High-quality CPR is an important determinant of survival from SCA.
  - More victims of out-of-hospital SCA should receive bystander CPR.
  - CPR must be performed effectively by bystanders and healthcare providers.

- Bystander CPR Saves Lives
  - Van Hoeyweghen (Belgium; 1993): Good BCPR: 16%; No BCPR: 6%; Poor BCPR: 4% (Good BCPR = 2.6 X survival)
  - Gallagher (New York; 1995): Good BCPR: 4.6%; Bad BCPR: 1.4%; (Good BCPR = 3.9 X survival)
  - Wik (Norway; 1994): Good BCPR: 24%; No BCPR: 4%; Poor BCPR: 1% (Good BCPR = 6 X survival)
Bystander CPR

- Without BCPR, survival decreases 7-10% for every minute of delay
- Bystander CPR rates are low in most communities (15-30%)
- Broaden Public CPR Training
  - AHA (Family and Friends CPR Anytime): 22-minute self-instruction
  - Community and corporate programs
  - Link to PAD programs
  - CPR in the Schools
  - Public service CPR training messages, 60-second CPR training, use of social media, and cell phone applications, mass training initiatives
- Dispatch-Assisted CPR
Dispatch-Assisted CPR

Challenges

- High number of centers
- Diversified administrative control as well as content and delivery of pre-arrival CPR instructions by dispatchers
- Inclusion of pre-arrival CPR instructions
- Training
- Cardiac arrest recognition
- Time to first compression: Van Vleet LM, Prehosp Emerg Care, 2012): 315 seconds (5.25 minutes)!

Dispatch-Assisted CPR Initiatives

- Simplified CPR arrest recognition (unresponsive, not breathing normally)
- Emphasis on providing dispatch-assisted CPR instructions
- Training programs
- CPR instruction CQI programs
- Reduction in time to first compression
Bystander CPR

- AHA Recommendations (*Circulation*, 2008)
  - Government agencies at the local, state, and federal level should provide CPR education in such settings as school systems and government-funded hospital and clinic systems.
  - The 9-1-1 and EMS systems should implement and support dispatch-assisted CPR programs.
  - CPR instructors, EMS leaders, and government agencies should strengthen public awareness of Good Samaritan laws and of the dramatic lifesaving potential of bystander CPR.
  - EMS systems and CPR instructors should focus efforts on rigorous CPR performance and quality-improvement efforts in resuscitation care; when CPR certification is needed, CPR instructional programs should always include an objective CPR quality assessment for certification.
  - Research funds should be targeted toward improving methods of CPR education, improving skill retention, and developing creative methods to widen the scope of current CPR training and education.
Defibrillation

Frank Pantridge, MD; Father of Emergency Medicine
Recognized that death from AMI was frequently due to VF, that defibrillation of VF in coronary care units was effective, but that most people had VF outside the hospital.

Invented the “portable defibrillator” in 1965 (154 pounds) placed in a mobile coronary care unit – established proof of concept.

Subsequently developed an “easy-to-carry” defibrillator (7 pounds) using miniature capacitor newly invented by NASA for rocketry; introduced the “Pantridge Plan” (mobile defibrillator in all ambulances and hospitals).

Strongly believed laypersons could and should be able to defibrillate – eventually invented the automated external defibrillator (AED).

Poorly recognized and adopted in England (Pantridge Plan not fully implemented until 1990!). Rapidly accepted and adopted in the US.
First Portable Defibrillator

1965: 154 pound adapted mains defibrillator and static inverter powered by two car batteries placed on a mobile cardiac care unit
Subsequent “Easy-to-carry” defibrillator (7 pounds) containing a miniature capacitor developed by NASA for rocketry and introduction of the “Pantridge Plan”
SURVIVAL

Chances of success reduced
7% to 10% each minute

Success

Time
EMT Defibrillation

- King County 1980 VF survival
- 7% without EMT – D
- 26% with EMT – D
# EMT Defibrillation

## Effectiveness of Early Defibrillation Programs

<table>
<thead>
<tr>
<th>Location</th>
<th>Before Early Defibrillation</th>
<th>After Early Defibrillation</th>
<th>Odds Ratio for Improved Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>King County, WA</td>
<td>7% (4/56)</td>
<td>26% (10/38)</td>
<td>3.7</td>
</tr>
<tr>
<td>Iowa</td>
<td>3% (1/31)</td>
<td>19% (12/64)</td>
<td>6.3</td>
</tr>
<tr>
<td>SE Minnesota</td>
<td>4% (1/27)</td>
<td>17% (6/36)</td>
<td>4.3</td>
</tr>
<tr>
<td>NE Minnesota</td>
<td>2% (3/118)</td>
<td>10% (8/81)</td>
<td>5.0</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>4% (32/893)</td>
<td>11% (33/304)</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Values are percent surviving and, in parentheses, how many patients had ventricular fibrillation.
Public Access Defibrillation

Public Access Defibrillation (PAD)

- Authorizing, training, and equipping laypersons with AEDs for use throughout the community
- Target collapse-to-defibrillation time of less than 3-5 minutes
PAD Legislation - Federal

- Good Samaritan Law (1970’s)
  - CPR

- Cardiac Arrest Survival Act
  - National Lobby
    - AHA, ACEP, ACC, NAEMSP, ENA, others
  - Exempts from Federal civil liability
    - User of AED
    - Provider of AED
PAD Legislation - Federal

- Amendment to the Cardiac Arrest Survival Act
- All Federal Buildings
  - Placement of AEDs
  - AED training
  - Guidelines for PAD
  - 600 or more employees
- All commercial airplanes
PAD Legislation - State

- All 50 States passed their own “Cardiac Arrest Survival Act”
- Similar lobby by many organizations
- Assisted by model legislation from AHA
- Protection by State PAD Legislation
  - Rescuer
  - Owner of AED
  - Provider of AED
  - Instructor
PAD Legislation - State

- **Conditions**
  - User is trained
    - 4-hour Heartsaver AED Course
  - Refresher training every 2 years
  - Device is maintained
  - PAD programs are coordinated with the ambulance system
  - Medical direction by a physician
AED Use

- Simple, easy to use
- Easier to learn than CPR
- Untrained sixth-grade children Vs. professionals*
  - 90 Vs. 67 seconds
  - Good pad placement
  - Clear during shock

Average Cardiac Arrest Survival

- Cities with Excellent Paramedics
  - Witnessed VF Arrests: 20 - 30%
  - All cardiac arrests: 9 - 14%
- All US Cities Combined
  - Witnessed VF Arrests: 12%
  - All cardiac arrests: 7%
- Chicago, New York
  - All cardiac arrests: 1 - 2%
21 patients; 18 with VF; 10/18 (56%) VF patients alive and neurologically intact at 1 year
Las Vegas Casinos*

- All cardiac arrests: 56 of 148 (38%)
- Witnessed VF: 56 of 105 (53%)
- Collapse to Defib: <3.0 min = 74%
- Collapse to Defib: >3.0 min = 49%

PAD - Police

Rochester, MN
- Police: 18 of 31 (58%)
- EMS: 23 of 53 (43%)
- Combined: 41 of 84 (49%)
- Call-to-shock: 5.8 versus 6.4 minutes

Pittsburgh, PA
- Police: 26%
- EMS: 3%
- AEDs independent predictor of survival
PAD - Airlines

- **Int’l Airline**
  - In-Flight: 2/6 (33%)
  - Terminal: 4/17 (24%)
  - Total: 6/23 (26%)

- **US Airline**
  - In-Flight: 6/11 (55%)
  - Terminal: 0/4 (0%)
  - Total: 6/15 (40%)
Public Access Defibrillation Phase I (PAD-1) Trial

- Prospective, randomized, multi-center
- 1000 public locations
- 24 cities in the US and Canada
- Funded by NIH, AHA, Industry
- Volunteer, non-medical responders
- Randomized: CPR Vs CPR and AED
Public Access Defibrillation (PAD) Trial

- Study endpoints
  - Survival to hospital discharge
  - Neurological outcome
  - Quality of life
  - Cost-effectiveness
  - Training and skills retention

- Data helped develop informed public policy regarding PAD by volunteer non-medical rescuers
Public-Access Defibrillation and Survival after Out-of-Hospital Cardiac Arrest

The Public Access Defibrillation Trial Investigators

Background

The rate of survival after out-of-hospital cardiac arrest is low. It is not known whether this rate will increase if laypersons are trained to attempt defibrillation with the use of automated external defibrillators (AEDs).

Methods

We conducted a prospective, community-based, multicenter clinical trial in which we randomly assigned community units (e.g., shopping malls and apartment complexes) to a structured and monitored emergency-response system involving lay volunteers trained in cardiopulmonary resuscitation (CPR) alone or in CPR and the use of AEDs. The primary outcome was survival to hospital discharge.

Results

More than 19,000 volunteer responders from 993 community units in 24 North American regions participated. The two study groups had similar unit and volunteer characteristics. Patients with treated out-of-hospital cardiac arrest in the two groups were similar in age (mean, 69.8 years), proportion of men (67 percent), rate of cardiac arrest in a public location (70 percent), and rate of witnessed cardiac arrest (72 percent). No inappropriate shocks were delivered. There were more survivors to hospital discharge in the units assigned to have volunteers trained in CPR plus the use of AEDs (30 survivors among 128 arrests) than there were in the units assigned to have volunteers trained only in CPR (15 among 107; P=0.03; relative risk, 2.0; 95 percent confidence interval, (1.07 to 3.77); there were only 2 survivors in residential complexes. Functional status at hospital discharge did not differ between the two groups.
PARADE Trial

- 112 AEDs to police
- Call to scene shortened 1.6 minutes
- Call to shock shortened 4.8 minutes
- VF/VT survival (P = NS)
  - Police (3/20) = 15%
  - EMS 16/160 = 10%
- AED equipped police responded first only 6.7% of the time
- 50% uncomfortable with rescuer role
PARADE Trial

“Simply providing police with AEDs is not enough. A careful review of the preexisting system should be undertaken. Many communities are dedicating resources only into AED purchase for nontraditional responders and not into system integration or outcome analysis. These communities will have a poor understanding about whether their AED programs are effective. This lack of awareness could be a major impediment to optimal use of AEDs to improve OHCA survival rates in the United States.”
What have we learned?

- It’s not the device, it’s the program!
Elements of a Successful Program

- Implement an initially effective program and then continuously maintain
  - PAD rescuer turnover
  - Skills maintenance - retraining
  - Device maintenance
  - Motivated participants
  - Maintain an effective internal emergency response plan
Prehospital 12-lead ECGs

- 50% of resuscitated cardiac arrest patients have acute coronary occlusion and 97% have CAD
- Because of improved hospital-based treatment of cardiac arrest in hospitals with cath labs and high volume, STEMI systems of care can be integrated into hospital-based treatment of resuscitated cardiac arrest
GISSI I TRIAL – OVERALL REDUCTION IN HOSPITAL (21 DAY) MORTALITY- 1987

# OF PTS 1,277  6,094  3,644  1,946  11,806

Mortality Reduction (%)

Hours Between MI Onset and Treatment

- <1 hour: P < .001 (47)
- <3 hours: P < .0005 (23)
- 3 - 6 hours: P < .03 (17)
- 6 - 12 hours: P = NS (2)
- All Pts: P = .0002 (18)
Average In Hospital Time Delay (Minutes)

Perceived: 30 minutes
Pre-Heart Project: 88.8 ± 54.4 minutes (N=211)

Am Heart J 1990;120:773-780
Rapid Identification and Treatment of the Ischemic Patient
Prehospital 12-lead ECGs

- Feasibility of use
- Diagnostic accuracy
- Significant reductions in time to hospital-based definitive treatment
- Feasibility of prehospital treatment with thrombolytic therapy
- Computerized ECG interpretation
- ECG-based predictive instruments
REDUCED HOSPITAL TREATMENT TIMES

- Seven prospective studies*

- Time savings: 20 – 61 minutes

*Am J Cardiol. 1990:66:786-791
Am J Cardiol. 1992;69:991-996
J Am Coll Cardiol. 1990;15:925-931
J AM Coll Cardiol. 1997:29;498-505
Heart 1997;78(5):456-461
Improved computerized ECG interpretations for AMI*

- Sensitivity = 71%, Specificity = 98%
- Positive Predictive Value
  - Computer = 94%
  - Physician = 86%

* Am Coll Cardiol. 1991;17:1486-1491
Gender Specific Computerized ECG Interpretation*

- Women with AMI have about 0.5 mm less ST elevation than men
- 14% improved detection of acute anterior MI in women under 60 years of age
- 28% improved detection of acute inferior MI in women under 60 years of age
- In use today

PATIENT ID: 200509091527
Thrombolytic Predictive Instrument probabilities
Age: 60 Gender: Male
HR: 92 bpm SBP/DBP: 120 / 70
Time Since onset: 0:0
History of Diabetes: No History of Hypertension: No

Predicted Outcomes: Without / With Thrombolysis
30 day Mortality 20% 3%
1 Year Mortality 30% 15%
Cardiac Arrest within 48 hours 4% 2%
Thrombolysis-Related Intracranial Hemorrhage 0.4%
Thrombolysis-Related other major bleed 3%
PRELIMINARY - MD MUST REVIEW
THE failure to hospitalize patients with acute myocardial infarction or unstable angina who present to the emergency department is a serious public health issue. Previous studies have found that between 2 percent and 8 percent of patients with acute myocardial infarction who present to the emergency department are sent home.¹⁻⁴ As many as 1.1 million patients have myocardial infarctions annually in the United States,⁵ about half of whom come to emergency departments. The rate of discharge of such patients represents at least 11,000 missed diagnoses of myocardial infarction.⁶⁻¹⁰

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ABSTRACT

Background Discharging patients with acute myocardial infarction or unstable angina from the emergency department because of missed diagnoses can have dire consequences. We studied the incidence of, factors related to, and clinical outcomes of failure to hospitalize patients with acute cardiac ischemia.

Methods We analyzed clinical data from a multicenter, prospective clinical trial of all patients with chest pain or other symptoms suggesting acute cardiac ischemia who presented to the emergency departments of 10 U.S. hospitals.
Prehospital 12-lead ECGs*

- National Heart Attack Alert Program
  - Reduced time to hospital treatment
  - Useful adjunct for rapid triage/treatment

- National American Heart Association Class I Recommendation

- Integrated into optimal cardiac arrest care

*Ann Emerg Med 1997 (1)29:1-87
*Circulation 2000;102(supp I):I-175-176
Professional Rescuer CPR
Poor Survival Rates after Sudden Cardiac Death
2000 cardiac arrest daily in the US!
~17% survive from in-hospital cardiac arrest
~7% survive from pre-hospital cardiac arrest
WHY?

10 - 20% of normal blood flow to the heart
20 - 30% of normal blood flow to the brain
CARDIAC OUTPUT DURING CPR

The Physiology of CPR
Compression

- Increases intrathoracic pressure and blood flow out of heart
  - Empties left ventricle
  - Immediately increases intracranial pressure (ICP), thereby increasing resistance to brain flow
  - Pushes air/O$_2$ out of lungs

Increases ICP
Decompression (Chest Wall Recoil)

- Lowers intrathoracic pressure relative to atmospheric pressure and rest of body
- Pulls blood back into right heart and helps refill left ventricle
- Draws air/O$_2$ into lungs
- Lowers ICP, thereby lowering resistance to blood flow
- Mimics ‘gasping’ reflex
Effect of Positive Pressure Ventilation

1. Delivers air/O₂ to lungs and re-inflates lungs, enabling gas exchange
2. Facilitates CO₂ clearance
3. Lowers resistance to trans-pulmonary blood circulation (improves R to L flow)
4. Increases ICP, lowering cerebral blood flow
5. Reduces venous blood return
6. Lowers cardiac output
7. Pushes blood out of lungs to left heart
8. Reduces interstitial fluid in lungs
Impedance Threshold Device (ITD) or ResQPOD®
Greater vacuum (negative pressure) in the chest during chest wall recoil leads to increased venous return and circulation and lower ICP.

**How an ITD Works**

- **Conventional CPR**
- **Conventional CPR with ITD**

**Enhanced Vacuum**
ITPR Application

ETP

1min

ITPR

ICP

PSR: SVST: Dia:

ICP

mmHg

sec
Cerebral Perfusion Pressure

$$\text{MAP} - \text{ICP} = \text{CePP}$$

↓ ITP: ↑ MAP - ↓ ICP = ↑↑ CePP
Human Data: Blood Pressure

BP after 14 Minutes of ITD Use

*Systolic BP

*p<0.05

Diastolic BP

n = 22

Milwaukee, WI

## ITD Clinical Trials with S-CPR

<table>
<thead>
<tr>
<th>Journal Citation</th>
<th>CPR Method</th>
<th>Trial Design</th>
<th># Pts in Control Group</th>
<th># Pts Treated w/ Active ITD</th>
<th>Endpoint</th>
<th>Results</th>
<th>P Value; Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pirrallo et al. Resuscitation 2005;66:13-20.</td>
<td>STD CPR ± ITD (sham vs active)</td>
<td>Prospective, double blind, randomized; prehospital</td>
<td>12</td>
<td>10</td>
<td>Systolic blood pressure</td>
<td>Sham: 43 ± 15 mmHg Active: 85 ± 20 mmHg</td>
<td>p = 0.001</td>
</tr>
<tr>
<td>Aufderheide et al. Crit Care Med 2005;33:734-740.</td>
<td>STD CPR ± ITD (sham vs active)</td>
<td>Prospective, double blind, randomized; prehospital</td>
<td>116</td>
<td>114</td>
<td>1*: Survival to ICU admission – all pts</td>
<td>Sham: 17.2% Active: 25.4%</td>
<td>p = 0.13; 1.64 (0.87, 3.10)</td>
</tr>
<tr>
<td>Thayne et al. Resuscitation 2005;67:103-108.</td>
<td>STD CPR ± ITD</td>
<td>Prospective vs historical control; prehospital</td>
<td>808</td>
<td>181</td>
<td>1*: Alive upon ED admission – all pts</td>
<td>No ITD: 22% With ITD: 34%</td>
<td>p = 0.005</td>
</tr>
<tr>
<td>Aufderheide et al. Crit Care Med 2008;36:S397-S404</td>
<td>STD CPR ± ITD</td>
<td>Prospective vs historical control; prehospital</td>
<td>1750</td>
<td>920</td>
<td>1*: Survival to hosp discharge – all pts</td>
<td>No ITD: 9.3% With ITD: 13.8%</td>
<td>p = 0.0008; 1.541 (1.192, 1.990)</td>
</tr>
<tr>
<td>Hinchey et al. Ann Emerg Med 2010;56(4):358-361.</td>
<td>STD CPR ± ITD</td>
<td>Prospective, 3-phase, systems-based approach vs historical control; prehospital</td>
<td>794</td>
<td>571</td>
<td>Survival to hosp discharge – all pts</td>
<td>No ITD: 7.3% With ITD: 11.5% Absolute increase from baseline to 34 phase: 4.2 to 11.5%</td>
<td>95% CI for absolute increase of 7.3% from baseline (3.7, 10.9)</td>
</tr>
<tr>
<td>Thigpen et al. J Resp Care 2010;55(8):1014-1019.</td>
<td>STD CPR ± ITD</td>
<td>Prospective, systems-based approach vs historical control; inhospital</td>
<td>246</td>
<td>261</td>
<td>1*: Survival to hosp discharge – all pts</td>
<td>No ITD: 17.5% With ITD: 26%</td>
<td>p = 0.006; 1.83 (1.17, 2.88)</td>
</tr>
<tr>
<td>Aufderheide et al. Heart Rhythm 2010;9(10):1357-1364.</td>
<td>STD CPR ± ITD</td>
<td>Prospective, systems-based approach vs historical control; prehospital</td>
<td>1641</td>
<td>1805</td>
<td>1*: Survival to hosp discharge – all pts</td>
<td>No ITD: 10.1% With ITD: 13.1%</td>
<td>p = 0.007; 1.34 (1.08, 1.68)</td>
</tr>
<tr>
<td>8</td>
<td>STD CPR ± ITD</td>
<td>Prospective, systems-based approach vs historical control; prehospital</td>
<td>107</td>
<td>247</td>
<td>1*: Survival to hosp discharge – all pts</td>
<td>No ITD: 8.4% With ITD: 19%</td>
<td>p = 0.011; 2.56 (1.17, 6.17)</td>
</tr>
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<td>9</td>
<td>STD CPR ± ITD (sham vs active)</td>
<td>Prospective, double blind, randomized, cross-over; prehospital</td>
<td>4345</td>
<td>4373</td>
<td>Survival to hosp discharge with good neurologic function</td>
<td>Sham: 5.8% Active: 6.0%</td>
<td>p = 0.71; (-1.1, 0.8)</td>
</tr>
</tbody>
</table>

*ITD implemented in the 2nd of 3 phases of system improvements.
Implementing the 2005 AHA Guidelines and Use of the Impedance Threshold Device Improves Hospital Discharge Rates after Out-of-Hospital Cardiac Arrest

<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>ROSC</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>Hospital Discharge</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>HD (VF)</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>Normal Neurological Function</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>

Aufderheide et al: Heart Rhythm 2010
In-hospital use of the ITD*

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>N=390</td>
<td>N=341</td>
</tr>
<tr>
<td>Survival to Hospital</td>
<td>20.7 %</td>
<td>35.8%*</td>
</tr>
<tr>
<td>Discharge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P < 0.001

Death by Hyperventilation

Ventilation rate: 47/min
Cerebral Perfusion Pressure

MAP – ICP = CePP

↓ ITP: ↑ MAP - ↓ ICP = ↑↑CePP

↑ ITP: ↓ MAP - ↑ ICP = ↓↓CePP
*P<0.05 between 12/min and 30/min
## Porcine Survival Study

<table>
<thead>
<tr>
<th>Breaths/Minute</th>
<th>O2/CO2</th>
<th>Survival Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>100% O2</td>
<td>6/7 (86%)</td>
</tr>
<tr>
<td>30</td>
<td>100% O2</td>
<td>1/7 (14%)*</td>
</tr>
<tr>
<td>30</td>
<td>95% O2/5% CO2</td>
<td>1/7 (14%)*</td>
</tr>
</tbody>
</table>

*P < 0.05
Chest Compression and Release

Aufderheide et al. Resuscitation 2005
Importance of Complete Chest Wall Recoil
Airway Pressure

Cerebral Perfusion Pressure

ICP 100%

CerPP 4 beat area during and after breath

mmHg x sec

100% during 100% w/o breath 75% during 75% w/o breath
60 consecutive resuscitations in which a first shock was administered for VF.

The primary outcome was first shock success defined as removal of VF for at least 5s following defibrillation.

Cases are grouped by 30 s average compression depth in approximately 11 mm (0.5 in.) intervals.

Chest compression depth of >50 mm (2 in.) represents current CPR guidelines recommendations.

Deeper chest compressions are significantly associated with increased probability of shock success. (Humans)
Pre-Shock Pause Duration and Defibrillation Success

Association between pre-shock pause and shock success.

Cases are grouped by pre-shock pause in 10 s intervals. Note that longer pre-shock pauses are significantly associated with a smaller probability of shock success.

The quality of CPR prior to defibrillation directly affects clinical outcomes.

Specifically, longer pre-shock pauses and shallow chest compressions are associated with defibrillation failure.

Resuscitation. 2006 Nov;71(2):137-45
Chest Compression Rate Correlation with Outcome

Subgroup of patients attaining ROSC is shown in gray; subgroup that did not, in black. Note 2 overlapping but distinct distributions, with mean rates for each group shown.

Mean rate, ROSC group: 90 ± 17 *
Mean rate, no ROSC group: 79 ± 18 *

*p = 0.0033

Average arrest duration (sec):
- ROSC group: 450 ± 403
- no ROSC group: 595 ± 390

Also note mean durations of resuscitation for 2 groups, demonstrating that the group that expired received longer resuscitation efforts on average, arguing against a "slow-code" bias.

Asterisk denotes statistical significance from 2-tailed t test as shown.

Coronary perfusion pressure approaches zero within seconds after stopping chest compressions.
The Quality of CPR Provided During Resuscitation Matters!
What Can We Do to Optimize Blood Flow to the Heart and Brain during CPR?

- Use the Impedance Threshold Device (2a)
- Provide high quality CPR
  - Avoid excessive ventilation rates (2a)
    - 6 breaths/minute (BLS)
    - 10 breaths/minute (ALS)
  - Avoid prolonged ventilation duration (2a)
    - 1 second/breath
  - Allow the chest to completely recoil after each compression (2b)
  - Do not stop chest compressions for longer than 10 seconds for any reason
  - Avoid rescuer fatigue
- Electronically measure quality of CPR and implement real-time and system-wide CPR CQI programs
Resuscitation Centers
## Overall Survival by Paramedic-Receiving Hospital in Milwaukee*

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Survival to HD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>31%</td>
</tr>
<tr>
<td>B</td>
<td>30%</td>
</tr>
<tr>
<td>C</td>
<td>29%</td>
</tr>
<tr>
<td>D</td>
<td>42%</td>
</tr>
<tr>
<td>E</td>
<td>29%</td>
</tr>
<tr>
<td>F</td>
<td>34%</td>
</tr>
<tr>
<td>G</td>
<td>29%</td>
</tr>
<tr>
<td>H</td>
<td>40%</td>
</tr>
</tbody>
</table>

Essential Elements of Resuscitation Centers*

- Integrated with EMS Medical Direction
- Aligned with STEMI Centers
- Initiate therapeutic hypothermia ASAP
- Capable of PCI
- Treats at least 40 resuscitated OOHCA patients/year
- Aggressive mechanical and pharmacologic hemodynamic support
- Electrophysiology testing, ICD assessment, and placement
- Defers neurological assessment until 72 hours after arrest
- Multi-disciplinary treatment team (EMS, emergency medicine, nursing, cardiology, neurology, critical care medicine, and social service support)

<table>
<thead>
<tr>
<th>Author</th>
<th>Population</th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oddo, et al</td>
<td>VF (79%)</td>
<td>37%</td>
<td>11% (p&lt;0.004)</td>
</tr>
<tr>
<td>Sunde, et al</td>
<td>VF (90%)</td>
<td>56%</td>
<td>26% (p&lt;0.001)</td>
</tr>
<tr>
<td>Knafelj, et al</td>
<td>VF STEMI</td>
<td>53%</td>
<td>19% (p&lt;0.001)</td>
</tr>
<tr>
<td>Wolfrum, et al</td>
<td>VF STEMI</td>
<td>69%</td>
<td>47%</td>
</tr>
<tr>
<td>Galeski, et al</td>
<td>VF STEMI</td>
<td>40%</td>
<td>22%</td>
</tr>
</tbody>
</table>
Survival to discharge was greater in CATH than in no CATH hospitals regardless of bed number.

Odds of death following hospital admission were significantly lower in hospitals with a cath lab.
Resuscitation Centers

- There is significant hospital variation in survival to discharge
- Some of the hospital characteristics that are associated with increased survival are presence of a cath lab and treatment of ≥ 40 resuscitated patients/year (STEMI Systems of Care)
- Essential elements of a Resuscitation Center should be a requirement for Resuscitation Center designation and survival rates/interventions should be monitored
- Resuscitation Centers should be integrated with EMS Medical Direction and OOHCA transport policies
- Effective EMS transport policies of resuscitated cardiac arrest patients to Resuscitation Centers will, at a minimum, double the community’s cardiac arrest survival rate
Summary

- We know what interventions are effective in increasing cardiac arrest survival.
- The science supporting these interventions is substantial.
- Goal: Optimize each link in the community’s chain of survival and forge a strong relationship between each link so that the sequence of interventions provided to cardiac arrest patients are consistently efficient, timely, high quality, and well coordinated.
- In achieving this goal, one can calculate estimated survival rate from the current 7% to.............
Calculating Estimated Improvement in Survival

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Effect</th>
<th>Survival Rate ↑ Over Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bystander CPR</strong>: in schools, homes &amp; public meeting places</td>
<td>• Rapid EMS notification</td>
<td>2 - 5%</td>
</tr>
<tr>
<td></td>
<td>• Start circulation</td>
<td></td>
</tr>
<tr>
<td><strong>AED Use</strong>: Widespread strategic AED deployment</td>
<td>• Reduce time to 1st shock in VF patients</td>
<td>4 - 6%</td>
</tr>
<tr>
<td><strong>Improved CPR Quality</strong></td>
<td>• Increase circulation to heart &amp; brain</td>
<td>4 - 6%</td>
</tr>
<tr>
<td>Prevent hyperventilation, continuous chest compressions, CPR pre/post shock</td>
<td>• Increase O₂ &amp; drug delivery</td>
<td></td>
</tr>
<tr>
<td>shock, intra-osseous drug delivery</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Impedance Threshold Device (ITD)</strong> BLS &amp; ALS deployment</td>
<td>• Increase circulation to heart &amp; brain</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>• Increase O₂ &amp; drug delivery</td>
<td></td>
</tr>
<tr>
<td><strong>Cooling, ICU, Cardiology</strong></td>
<td>• Revascularization</td>
<td>10 - 15%</td>
</tr>
<tr>
<td>Standard hypothermia protocols, cardiac angiography (including during CPR)</td>
<td>• Prevent sudden cardiac death</td>
<td>25 - 37%</td>
</tr>
<tr>
<td>&amp; EP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Thank you!