What Works (& Doesn’t Work) in Cardiac Arrest Resuscitation

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We will discuss…….

• Reordering the Alphabet
• Cardiopulmonary Resuscitation
• Defibrillation
• Airway Management
• Vascular Access
• Medication Administration
• Post-Resuscitation Care
In the old days......

• The “ABCs”  
  ...Airway........Breathing.........Circulation....

• Significant emphasis in all patients...
  – Defibrillation
  – Invasive airway placement
  – Cardioactive medications

• Less emphasis on high quality, uninterrupted chest compressions
Today....

• The “CABs”
• Emphasis on....
  – Chest compressions
  – Defibrillation
  – Recognition of non-cardiac causes with tailored RX
  – Post-resuscitation care
• “Less of a priority”
  – Placement of invasive airways **early**
  – Cardio-active medication administration
• Limit interruptions in chest compressions
And remember......

• Few issues are absolute in life

• We know that...
  – ...early response, chest compressions &
    defibrillation are awesome interventions
  – ...early invasive airways & early cardioactive
    medications are less awesome

• Less awesome, not “bad” or “wrong” or “incorrect” or “harmful”
Relative Importance of Interventions in Cardiac Arrest
Adjusted Odds Ratio

Witnessed Arrest with Bystander
4.4 (3.1 - 6.4)

Bystander CPR
3.7 (2.5 - 5.4)

Defibrillation < 8 min
3.4 (1.4 - 8.4)

Advanced Life Support
1.1 (0.8 - 1.5)
Interventions in Cardiac Arrest

Figure 2. Actual versus Predicted Interrupted-Time-Series Model for Survival to Discharge for 100 Consecutive Months, from the Rapid-Defibrillation Phase to the Advanced-Life-Support Phase.

The solid line represents actual survival, and the dotted line represents predicted survival based on the rapid-defibrillation phase.

Stiell NEJM 2004
Part 1: Executive Summary: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care


Circulation 2010;122:S640-S656
DOI: 10.1161/CIRCULATIONAHA.110.970889
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- Immediate recognition of cardiac arrest and activation of the emergency response system
- Early CPR with an emphasis on chest compressions
- Rapid defibrillation
- Effective advanced life support
- Integrated post–cardiac arrest care
Cardiopulmonary Resuscitation
**Cardiopulmonary Resuscitation**

- **EXTREMELY** important intervention
- Traditional vs Compression-only
- High-quality compressions
  - Rate of 100/minute
  - 2-3 inch depth
  - Minimize interruptions
CPR vs Nothing

Some Form of CPR is Better than Nothing


• Out-of-hospital cardiac arrest (#7265)
• Three groups
  – No CPR -- 44.1%
  – Dispatcher-assisted – 25.7%
  – Bystander CPR – 30.2%
• Overall Survival 15.3%
• Compared to no CPR, adjusted ORs of survival....
  – Dispatcher-assisted -- 1.45 (95% CI 1.21, 1.73)
  – Bystander -- 1.69 (95% CI 1.42, 2.01)
CPR – What Form is Better?

Nothing vs Traditional vs Compression – only

- None [72%]
- Ventilation & Compression [17%]
- Compression Only [11%]

Japan
Urban setting
Outpatient cardiac arrest
Survival
5% “CR” vs 2.2% none
No ventilation benefit

SOS-KANTO Study Group. Lancet 2007;369:920
CPR – What Form is Better?
Nothing vs Traditional vs Compression – only

- United States
- Urban setting
- Outpatient cardiac arrest
- No ventilation benefit

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Occurrence</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression Only</td>
<td>544 (12%)</td>
<td>4.3%</td>
</tr>
<tr>
<td>Ventilation &amp; Compression</td>
<td>783 (16%)</td>
<td>4.1%</td>
</tr>
<tr>
<td>None</td>
<td>3550 (72%)</td>
<td>2.5%</td>
</tr>
</tbody>
</table>

Ewy GA. Circulation 2007;116:2894
Traditional vs Compression-only

Compressions are Most Important


- Out-of-hospital cardiac arrest (#520)
- Compression Only-CPR vs Traditional CPR
  - Dispatcher-assisted
  - CO-CPR: #241, 81% “successful”
  - T-CPR: #279, 62% “successful”
  - 1.4 minutes less time for CO-CPR
- Survival
  - CO-CPR: 14.6%
  - T-CPR: 10.4%
Early & Late in Resuscitation

Ventilations Have Some Value...Later


• Prehospital arrest (#4902)
• Comparison
  – Compressions in early arrest (#544) – any form of CPR with compressions
  – Traditional CPR in prolonged arrest (#783)
• Outcome: 1 yr survival & good neuro status
• Outcomes:
  – Short duration (< 15 min)
    
    None - 2.5%
    Compressions - 4.3%, OR 1.72
    Traditional - 4.1%; OR 1.57
  
  – Prolonged duration (> 15 min)
    
    None - 0.3%
    Compressions - 0
    Traditional - 2.2%
Basic vs Advanced Care with CPR
Which is better?

- Out-of-hospital cardiac arrest # 95,072 in Japan
- Comparison of bystander +/- ALS care
  - Bystander CPR (B-CPR) vs ALS by EMS & MDs
- 8.1% alive @ 30 days - 2.8% with good neuro status
- Compared to EMS without B-CPR

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Adjusted OR</th>
<th>95%CI with P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMS with B-CPR</td>
<td>2.23</td>
<td>0.05 - 2.42 / &lt; 0.01</td>
</tr>
<tr>
<td>MD without B-CPR</td>
<td>1.18</td>
<td>0.86 - 1.61 / 0.32</td>
</tr>
<tr>
<td>MD with B-CPR</td>
<td>2.8</td>
<td>2.28 - 3.43 / &lt; 0.01</td>
</tr>
</tbody>
</table>

- Bystander CPR most significant - survival with good neuro status

Yasunaga H et al, Crit Care 2010;14:R199
PUSH HARD, DEEP, & FAST
Compression Depth

- Deeper compression depths eject more blood per compression
- Improved perfusion
- Better outcomes
PUSH HARD & DEEP!
Deeper compressions are significantly associated with ROSC

Edelson et al, Resuscitation 2006;71:137
Compression Rate

• More rapid rates of compression increase cardiac output

• Improved perfusion

• Better outcomes

• Difficult to attain
Chest Compression Rates During Cardiopulmonary Resuscitation Are Suboptimal
A Prospective Study During In-Hospital Cardiac Arrest

Benjamin S. Abella, MD, MPhil; Nathan Sandbo, MD; Peter Vassilatos, MS; Jason P. Alvarado, BA; Nicholas O’Hearn, RN, MSN; Herbert N. Wigder, MD; Paul Hoffman, CRT; Kathleen Tynus, MD; Terry L. Vanden Hoek, MD; Lance B. Becker, MD

Background—Recent data highlight a vital link between well-performed cardiopulmonary resuscitation (CPR) and survival after cardiac arrest; however, the quality of CPR as actually performed by trained healthcare providers is largely unknown. We sought to measure in-hospital chest compression rates and to determine compliance with published international guidelines.

Methods and Results—we developed and validated a handheld recording device to measure chest compression rate as a surrogate for CPR quality in a prospective observational study of adult cardiac arrests that occurred at 3 hospitals from April 2002 to August 2006. Arrests were witnessed in 84% of cases. Using a customized personal digital assistant programmed to store the exact time of each chest compression, allowing offline calculation of compression rates at serial time points. In 97 arrests, data from 75 minutes during which chest compressions were delivered were analyzed in 30-second time segments. In 36.9% of the total number of segments, compression rates were <80 compressions per minute (cpm), and 21.7% had rates <70 cpm. Higher chest compression rates were significantly correlated with initial return of spontaneous circulation (mean chest compression rates for initial survivors and nonsurvivors, 90±17 and 79±18 cpm, respectively; P=0.0033).

Conclusions—in-hospital chest compression rates were below published resuscitation recommendations, and suboptimal compression rates in our study correlated with poor return of spontaneous circulation. CPR quality is likely a critical determinant of survival after cardiac arrest, suggesting the need for routine measurement, monitoring, and feedback systems during actual resuscitation. (Circulation. 2005;111:428-434.)

Key Words: cardiopulmonary resuscitation  □ death, sudden □ heart arrest
VERY IMPORTANT
DO NOT STOP
Compression Interruptions

• Interruptions halt all perfusion
• Magnitude of interruptions
  – ~30 sec - pulse check
  – ~20 sec - rhythm check
  – ~240 sec - placement of invasive airway
  – ~15 sec - defibrillation
• Sobering facts
  – Each 10 sec of no compressions reduces survival by 5%
  – Resumption of CNS perfusion after compressions requires 40-45 sec
Each 10 sec of No Compressions Reduces Survival by 5%
Chest compressions were not delivered half of the time & most compressions were too shallow.
Quality of Cardiopulmonary Resuscitation During In-Hospital Cardiac Arrest

Benjamin S. Abella, MD, MPhil
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Helge Myklebust, BEng
Daniel B. Morgan, MD
Anne Barry, RN, MBA
Nicholas O’Hearn, RN, MSN
Terry Tyler, RN, BSN, MD
Lance B. Becker, MD

Again, chest compressions were not delivered more than half of the time & most compressions were too shallow. 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.

Main Outcome Measure Adherence to American Heart Association and international CPR guidelines. Results The analysis of 10 minutes of resuscitation by 30 rescuer segments revealed that chest compression rates were less than 90/min in 28.1% of segments. Compression depth was too shallow (defined as <38 mm) for 37.4% of compressions. More than half of the patients experienced an arrest without chest compressions; if a 10-second pause each minute of arrest would yield a no-flow fraction of 0.17. A total of 27 patients (40.3%) achieved return of spontaneous circulation and 7 (10.4%) were discharged from the hospital.

Conclusions In this study of in-hospital cardiac arrest, the quality of multiple parameters of CPR was inconsistent and often did not meet published guideline recommendations, even when performed by well-trained hospital staff. The importance of high-quality CPR suggests the need for rescuer feedback and monitoring of CPR quality during resuscitation efforts.

JAMA. 2005;293:305-310
Compression Interruptions

• Interruptions are bad!

• We want to strive towards a significant reduction in compression interruptions

• Avoid *resuscitatus interruptus*
ROSC & Coronary Perfusion Pressure

Higher compression rates without interruption are associated with better perfusion.

Ewy G, Circulation 2005
ROSC & Coronary Perfusion Pressure

Higher compression rates without interruption are associated with better perfusion.

Paradis JAMA 1990
Standard CPR

Blood pressure

Time

| = chest compression

Berg et al, 2001
Inadequate Perfusion During Cardiac Arrest as Chest Compressions Resume After Interruption
Chest Compressions During Cardiac Arrest

Magnitude of Perfusion Resulting from Chest Compressions

- Continuous Compressions with “Best Possible” Perfusion
- Compressions Halt
- Inadequate Perfusion
- Compressions Resume
- No Perfusion

Systolic Blood Pressure (mmHg) vs. Time
Compression Only

Blood pressure

Time

= chest compression

Berg et al, 2001
Perfusion During Cardiac Arrest with Chest Compressions

Systolic Blood Pressure (mmHg)

Systolic Blood Pressure (mmHg)

Time

Time
**Continuous Chest Compressions**

**Chest Compression Fraction**

- Out-of-hospital cardiac arrest

- Chest compression fraction = \( \frac{\text{Compression}}{\text{Total Resuscitation}} \)

<table>
<thead>
<tr>
<th>#1029 VF victims</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing CCF associated with better outcome</td>
</tr>
<tr>
<td>Depth &amp; rate were inversely related</td>
</tr>
<tr>
<td>Higher rates of ROSC</td>
</tr>
<tr>
<td>- Increased rate</td>
</tr>
<tr>
<td>- Increased depth</td>
</tr>
</tbody>
</table>

Stiell et al, Crit Care Med, epub Jan 2012

<table>
<thead>
<tr>
<th>#2103 non-VF/VT victims</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing CCF associated with better outcome</td>
</tr>
<tr>
<td>Adjusted OR for ROSC for each CCF category</td>
</tr>
<tr>
<td>- 41-60% -- 1.14</td>
</tr>
<tr>
<td>- 61-80% -- 1.42</td>
</tr>
<tr>
<td>- 81-100% -- 1.48</td>
</tr>
</tbody>
</table>

Vaillancourt et al, Resuscitation, 2011;82:1501-7

- **Bottom line** = improved outcome ~ more compressions
Chest Compressions & Recoil

• Full re-expansion of thoracic cavity after a single compression
• Theoretically allows for more cardiac filling & therefore greater cardiac output
• Demonstrated in animal models
• Not yet shown in humans
CPR Devices

Surprisingly Equivocal Outcomes
Defibrillation

• Only for pulseless VT & VF
• Shock as soon as possible
• One shock vs “stacked shocks”
• Device-specific maximal energy
• Limit interruptions in chest compressions
• Automatic external defibrillators
Defibrillation

When should we shock?

• Controversial – when should we shock pulseless VT & VF?
• Compressions 1\textsuperscript{st}, shock 1\textsuperscript{st}, or what?
Immediate Shock vs CPR?


Pro – delay to defibrillation

- Investigate impact of CPR prior to 1st shock
- Retrospective analysis
  - Witnessed out-of-hospital VF cardiac arrest
  - Compared 2 approaches
    - Mandated EMS approval for shock (CPR 1st) -- #143
    - Immediate shock -- #100
- CPR 1st group
  - More CPR prior to 1st shock
  - Higher rate of favorable neurologic outcome at 30 days (28% vs 14%) & 1 year (26% vs 11%)

Additional 2 of 3 papers supportive of “delayed” defibrillation
Immediate Shock vs CPR?
Simpson et al, Resuscitation 2010

Con – delay to defibrillation

• Systematic review / meta-analysis – 3 trials
• Results..... response time < 5 min & > 5 min
  – No benefit to providing CPR before defibrillation vs. immediate defibrillation
  – No harm to performance of CPR before defibrillation
Compressions or Defibrillation First?

- 9933 out-of-hospital cardiac arrest patients
- 5290 early / 4643 late rhythm analysis
- Subsequent defibrillation as appropriate
- Outcome – survival to D/C with intact neuro status
- 273 (5.9%) / 310 (5.9%) reached study endpoint
- No outcome difference
Immediate Shock vs CPR?

• What should we do?

• AHA has reduced the strength of its recommendation of shock first in delayed response / prolonged down times

“Note that EMS [and hospital] systems exercise operational & medical judgment in determining the time of first defibrillation”
Defibrillation

# Shocks

- Initial delivery of single shock
  - Followed by immediate CPR
First Shock Efficacy (Termination of VF)

Stacked shock approach with biphasic energy

No increased chance of successful defibrillation with biphasic energy

<table>
<thead>
<tr>
<th>N</th>
<th>Waveform Energy</th>
<th>VF Termination 1st shock</th>
<th>VF Termination 2nd shock</th>
<th>VF Termination 3rd shock</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td>Biphasic 150J, 150J, 150J</td>
<td>96%</td>
<td>96%</td>
<td>98%</td>
</tr>
<tr>
<td>48</td>
<td>Monophasic 200J, 300J, 360J</td>
<td>54%</td>
<td>60%</td>
<td>67%</td>
</tr>
</tbody>
</table>

Martens 2001
Defibrillation

Energy

- Energy issues
  - Device specific recommendations
  - If in doubt, device-specific MAXIMUM
Chest Compression Interruptions
Due to Electrical Charging for Electrical Defibrillation

• Inpatient setting -- 562 shocks in 244 cardiac arrests
• Three methods of defibrillator charging
  – “Halted” method
    • Rhythm check w/o compressions
    • If shockable, charge & shock
    No compressions for 14.8 sec
  – “Interrupted” method (AHA)
    • Rhythm check w/o compressions
    • If shockable, resume compression & charge
    • Then halt & shock
    No compressions for 11.5 sec
  – “Anticipatory” charging
    • Charge defibrillator prior to rhythm check
    • Rhythm check w/o compressions
    • If shockable, shock
    • “Dump” charge if no shock
    No compressions for 3.9 sec

Edelson et al, Resuscitation 2010.
Chest Compression Interruptions Due to Electrical Defibrillation

- I’m clear, you’re clear, we’re all clear!
  - Does it really matter?

- 39 patients / 43 shocks
  - Elective cardioversion
  - Simulated CPR contact
  - Standard gloves worn / self-adhesive pads

- No issue for rescuer
  - No perceptible shock
  - Average leakage current very low

Lloyd MS et al, Circulation 2008;117:2510
ECG Filtering during Active Chest Compressions

Unfiltered - Standard Monitoring
ECG Monitoring -- Chest Compressions

Filtered - Enhanced Monitoring
ECG Monitoring -- Chest Compressions
Automatic External Defibrillator
Automatic External Defibrillator

- Portable, automatic defibrillator
- Easy to use
- Safe to use
- Can be life saving
- Markedly reduce the time to defibrillation
- Used in conjunction with CPR
AED vs Standard Response
AEDs Reduce Time to Shock & Improve Outcome

- Time to first shock / outcome with neurologic status
- 2833 consecutive cardiac arrest patients
  - AED on-site #128
  - AED distant #478
  - EMS Response #2227

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Time to Shock (min)</th>
<th>Survival (%)</th>
<th>Odds Ratio (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AED on site</td>
<td>4.1</td>
<td>49.6</td>
<td>2.72 (1.77-4.18)</td>
</tr>
<tr>
<td>AED distant</td>
<td>8.5</td>
<td>14.2</td>
<td>1.07 (0.82-1.39)</td>
</tr>
<tr>
<td>Response</td>
<td>11.0</td>
<td>5.6</td>
<td>------------------</td>
</tr>
</tbody>
</table>

Berdowski et al, Circulation 2011;124:2225
Chicago Airports AED Program

- 33 AEDs at O'Hare
- 7 AEDs at Midway

Survival

- VF: 13
- Non-VF: 3
- Survival: 9 (69%)
- Survival: 0 (0%)

16 arrests

- Replicated at other airports
  - Logan 21% survival
  - LAX 26% survival

Caffrey et al, NEJM 2002
Las Vegas Gaming Casinos
Valenzuela TD et al, NEJM 2000

- < 3 min to DF AED placement
- Security officers
- DF first, then CPR

86% witnessed arrest
Collapse to DF -- 4.4 min
Collapse to EMS -- 9.8 min

105 VF arrests
Survival to discharge
56 (53%)
Prospective / multicenter clinical trial
Randomly assigned community units
  - Lay volunteers trained in CPR vs CPR / AED
Primary outcome -- survival to discharge
Survival
  - CPR / AED -- 30 among 128 (23%)
  - CPR only -- 15 among 107 (14%)
No inappropriate shocks
Targeted First Responder
Police Application

• Myerburg et al, Circulation 2002
  – Urban // suburban PD
  – Reduced time to Rx / improved outcome in VF

  – Suburban // PD first-responders
  – Increased rate of VF survival

• Forrer et al, Resuscitation 2002
  – Suburban // PD with AED
  – Cost-effective intervention
Airway Management
Airway Management

• Once thought to be very important
• Now known to be of less value
  – Particularly early in resuscitation
  – Impact is not negative
  – But distractions / interruptions are negative
Airway Management

- **Options**
  - None
  - 100% face mask / oral airway
  - Bag-mask ventilations
  - Supra-glottic airways
  - Endotracheal intubation
  - Surgical airways

- **Relative value**
  - Less value early in cardiac-based cardiac arrest
  - More value in non-cardiac-based cardiac arrest

- In either instance, do not allow interruptions in compressions due to airway placement
Cardiac-based Cardiac Arrest
Arterial Blood Gas
after 7 min of CPR for VF

<table>
<thead>
<tr>
<th></th>
<th>O$_2$ Sat</th>
<th>pCO$_2$</th>
<th>pH</th>
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</thead>
<tbody>
<tr>
<td>Compressions &amp; Ventilations</td>
<td>92±1*</td>
<td>25±2</td>
<td>7.49±.02</td>
</tr>
<tr>
<td>Compressions Only</td>
<td>76±6*</td>
<td>37±5</td>
<td>7.41±.03</td>
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</table>

* p<0.01

Berg, *Circulation* 1997
Noncardiac-based Cardiac Arrest
Arterial Blood Gas
after 7 min of CPR with asphyxia

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<tr>
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<td>Compressions &amp; Ventilations</td>
<td>87±6*</td>
<td>45±8*</td>
<td>7.20±.02*</td>
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<tr>
<td>Compressions Only</td>
<td>17±5</td>
<td>97±5</td>
<td>7.01±.06</td>
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</table>

* $p<0.001$

Berg, *Circulation* 1997
Placement of Invasive Airway Prehospital Endotracheal Intubation

- Utstein registry (2007) -- #109,461
- Considered ROSC @ event & neuro status @ 1 month

<table>
<thead>
<tr>
<th>Outcome</th>
<th>RR [95 CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROSC</td>
<td>0.61 [0.54-0.69]</td>
</tr>
<tr>
<td>Neuro Status</td>
<td>0.47 [0.38-0.57]</td>
</tr>
</tbody>
</table>

- Invasive airways were not associated with favorable outcome
Placement of Invasive Airway Prehospital Endotracheal Intubation


- EMS setting in Japan - 649,654 events
  - Outcomes: Primary - favorable neuro status @ 1 month; secondary - survival @ 1 month
  - 57% BVM & 43% advanced airway (6% ETT & 37% SGA)
  - Adjusted for all appropriate variables

- Adjusted OR for neuro intact survival for advanced airway placement - 0.38 (95% CI 0.37-0.40)

- Similar results for ETT & SGA individually
Placement of Invasive Airway Hospitalized Patients #25,006

- Invasive airway placement
  - After onset & during event
  - Considered time from onset to airway placement
  - 40,772 (62%) patients with airway placement after ROSC (excluded)
  - Mean time to placement 5.9 minutes

- Outcomes

<table>
<thead>
<tr>
<th>Event</th>
<th>Occurrence</th>
<th>Adjusted Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Early vs Late Airway</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROSC</td>
<td>50.3% (49.7-51.0)</td>
<td>0.96 (0.91 – 1.01)</td>
</tr>
<tr>
<td>Survival to 24 hr</td>
<td>33.7% (33.1-34.3)</td>
<td>0.94 (0.89 – 0.99)</td>
</tr>
<tr>
<td>Survival to D/C</td>
<td>15.3% (14.9-15.8)</td>
<td>Unable to analyze</td>
</tr>
</tbody>
</table>

- No increase in ROSC
- MINIMAL increase in 24 hr survival
- Analysis not possible for survival to D/C & neuro outcome

Wong, Resuscitation, 2010;81:182
Chest Compression Interruptions Due to Endotracheal Intubation

- Out-of-hospital cardiac arrest -- #100
- Endotracheal intubation interruptions
  - Average 2 interruptions per arrest
  - Range 1-9 interruptions
  - Average single interruption – 47 sec
  - Total interruptions – 221 sec
- ~25% CPR interruptions

Chest Compression Interruptions
Due to Intubation -- “Minimally Interrupted” CPR

- Compared passive oxygen “flow” vs. BVM ventilation
- 1,019 out-of-hospital cardiac arrest events
  - 459 passive oxygen & 560 BVM ventilation
- Among witnessed arrests with VT/VF
  - Passive oxygen - 38% neuro-intact survival
  - BVM ventilation - 26% neuro-intact survival
- Similar outcomes in unwitnessed & nonshockable rhythms
- Theorized...fewer compression interruptions improved outcome

Please Avoid “Death by Hyperventilation”
Compressions & Blood Flow

- **Cardiac Pump Theory**
  - “Compressive” approach
  - Heart is “squeezed” between the breastbone & spine

- **Thoracic Pump Theory**
  - “Pressure” approach
  - Chest acts like a bellows
  - Compressions increase pressure & produce cardiac output
  - Release decreases pressure, allowing the heart to refill (preload)
Hyperventilation-Induced Hypotension During CPR

- Observational study n=21 (Milwaukee)
- Ventilation rates were too high
- Excessive vent rates produce
  - Increased positive intrathoracic pressure
  - Decreased coronary perfusion
  - Decreased survival rates

Aufderheide, Circulation 2004
Impedance Threshold Devices

Concept is Very Important

Clinical Trials – Equivocal Outcomes
Vascular Access
Vascular Access in Cardiac Arrest

- **Peripheral venous access**
  - Preferred approach

- **Intra-osseus access**
  - Very acceptable alternative
  - At times, preferred technique

- **Central venous access**
  - Rarely the access of initial choice
  - Reasonable in certain circumstances
    - Large volume resuscitation
    - Placement after resuscitation
Vascular Access in Cardiac Arrest

- IO vs IV access
- Prehospital setting – nontraumatic arrest
- Randomized to: tibial IO vs humeral IO vs IV
- Outcome – rate of first-success placement
- 182 patients: 64 (tibial IO), 51 (humeral IO), 67 (peripheral IV)
- First-success placement
  - Tibial IO – 91%
  - Humeral IO – 51%
  - Peripheral IV – 43%

IV Placement / Medications in Cardiac Arrest?


Explored the “removal of intravenous drug administration from an ALS protocol” & its impact on survival

- Out-of-hospital cardiac arrest (#1183) – 5 years in Oslo, Norway
- ALS therapy with & without IV medications
- Outcome: survival to event, discharge, & 1 year; also considered impact on CPR & ultimate neuro status
- Impact on CPR -- negligible
- Adjusted odds ratio for survival as a function of medication use -- 1.15; 95CI, 0.69-1.91

<table>
<thead>
<tr>
<th>Therapy</th>
<th>ROSC</th>
<th>Survival to D/C</th>
<th>1 Year Survival</th>
<th>Neuro Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>With IV</td>
<td>32.0</td>
<td>10.5</td>
<td>10.0</td>
<td>9.8</td>
</tr>
<tr>
<td>(#418)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without IV</td>
<td>21.0</td>
<td>9.2</td>
<td>8.0</td>
<td>8.1</td>
</tr>
<tr>
<td>(#433)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* P< 0.001

Adjusted odds ratio for survival: IV Therapy 1.15 (0.69 – 1.91)
Medication Administration
Medication Administration

• Range of agents
  -- Vasopressors
  -- Anti-arrhythmic agents
  -- Buffers
  -- Electrolytes
  -- Fibrinolytic agents

• Benefit is?
  -- negligible?
  -- equivocal?
  -- modest?
  -- significant?

• Some benefit in selected patients
Medications in Cardiac Arrest


Milwaukee

• ALS unit
• Standard “North American” ACLS Rx
• Witnessed – 25%
• Bystander CPR – 27.1%
• Initial rhythms – more PEA / asystole
• Survival to D/C – 7.2%

Edinburgh

• ALS unit
• Resuscitation Rx [BLS, Defib, Airway, IVF]
• Witnessed – 65.7%
• Bystander CPR – 42.3%
• Initial rhythms – more VF
• Survival to D/C – 12.4%

?? Impact of Medications in Cardiac Arrest Resuscitation ??
Vasopressor Therapy
Bolus Vasopressor Therapy

-- Epinephrine --

-- Vasopressin --
Epinephrine
Jacobs et al, Resuscitation 2011;82:1138

• Out-of-hospital cardiac arrest
  – Epinephrine (1:1000) 1 mg vs placebo
  – Therapy per ALS guidelines
  – Matched for demographics & resuscitation RX

• 4103 patients – 534 analyzed: 272 EPI vs 262 Placebo

<table>
<thead>
<tr>
<th></th>
<th>ROSC</th>
<th>Survival to D/C*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epinephrine</td>
<td>64 (23.5%)</td>
<td>11 (4.0%)</td>
</tr>
<tr>
<td>Placebo</td>
<td>22 (8.4%)</td>
<td>5 (1.9%)</td>
</tr>
</tbody>
</table>

• Conclusion: EPI does not alter outcome

* OR = 2.2; 95 CI 0.7 - 6.3
Epinephrine
Nakahara et al, Acad Emerg Med 2012
Association between timing of epinephrine administration and intact neurologic survival following out-of-hospital cardiac arrest in Japan: a population-based prospective observational study

• Explored impact of early epinephrine on witnessed out-of-hospital cardiac arrest outcome WITH IMPORTANT CONTROL OF BIAS (removal early responders from analysis)


• Outcomes -- intact neurologic survival, any survival at 1 month / at discharge
Epinephrine
Nakahara et al, Acad Emerg Med 2012
Association between timing of epinephrine administration and intact neurologic survival following out-of-hospital cardiac arrest in Japan: a population-based prospective observational study

• Early epinephrine ($\leq 10$ min) was associated with...
  
  higher intact neurologic survival $[\text{OR}=1.39, \text{CI}=1.08-1.78]$ 
  & any survival $[\text{OR}=1.73, \text{CI}=1.46-2.04]$ 
  ....compared to no epinephrine Rx

• Authors concluded that “…early epinephrine administration may be associated with higher rates of intact neurologic survival...”
• In general, epinephrine was associated with greater chance of poor outcome

• Subgroup analysis
  – VF patients with **EARLY** epinephrine use (< 10 minutes)
  – Higher rate of neurologically intact survival (66.7% vs 24.9% in non-epinephrine group)

• Niche application of epinephrine use
Vasopressor Therapy in Cardiac Arrest -- Vasopressin

- Stiell et al, Lancet 2001 -- inpatient
  - No difference in survival & neurologic function

  - No difference in VT/VF & PEA outcomes

  - No difference in survival to D/C & neurologic outcome

- All with more frequent ROSC at event
Vasopressor Therapy in Cardiac Arrest
Stiell et al, Lancet 2001

• Prospective, randomized, triple-blinded study
• Inpatient cardiac arrest victims
  – Vasopressin 40 U vs epinephrine 1 mg
  – Outcome: survival to hospital discharge & neurologic status
• 200 patients: 104 vasopressin & 96 epinephrine
• No difference:
  – Survival
  – Neurologic function
Vasopressor Therapy in Cardiac Arrest
Wenzel V et al, NEJM 2004

- Randomized trial
- Prehospital cardiac arrest
  - Vasopressin vs epinephrine
  - Additional epinephrine as needed
  - Primary end point -- survival to admission / discharge
- 1219 patients
Vasopressor Therapy in Cardiac Arrest
Wenzel V et al, NEJM 2004

- No significant differences in VF & PEA
- Aystole – improved outcome

• Increased effectiveness for epinephrine as 2\textsuperscript{nd} line agent
Vasopressin vs Epinephrine in Cardiac Arrest

• Out-of-hospital cardiac arrest victims
• Random assignment
• Interventions
  EPI 1 mg/VSP 40 IU
  EPI 1 mg
  Placebo

Similar subsequent agents / doses

Gueugniaud et al, NEJM 2008
Vasopressin vs Epinephrine in Cardiac Arrest

- 1442 patients EPI + VP vs 1452 patients EPI
- 80% of patients with asystole
- No significant difference
  - Survival to hospital admission
  - ROSC
  - Survival to hospital discharge
  - 1-year survival
  - Neurologic outcome

Gueugniaud et al, NEJM 2008
Vasopressin vs Epinephrine with Steroids in Cardiac Arrest

• Inpatient cardiac arrest – #100

• Interventions / CPR cycle
  – Saline + EPI (1 mg) -- [#52]
  – VSP (20 IU) + EPI (1 mg) + methylprednisolone (40 mg) -- [#48]
  – Post-resuscitation shock – hydrocortisone 300mg daily 7 days

• Single-enter, prospective, randomized, double-blind, placebo-controlled, parallel-group trial

• End points: ROSC & survival to D/C

Mentzelopoulos et al, Arch Int Med 2009
Vasopressin vs Epinephrine with Steroids in Cardiac Arrest

- Resuscitation & hospital D/C rates were higher in the steroid group
- Hemodynamics, CVO$_2$ saturation, & organ failure-free days – improved in steroid group

Mentzelopoulos et al, Arch Int Med 2009
Vasopressors in Cardiac Arrest
Cantrell et al, Prehosp Emerg Care 2013

“Impact of Delayed and Infrequent Administration of Vasopressors on Return of Spontaneous Circulation during Out-of-Hospital Cardiac Arrest.”

• Retrospective – cardiac arrest in 10 EMS systems
• Use of vasopressors & impact of “Rx delay”
• 660 patients
  -- Response time 8.8 min
  -- Bystander CPR 46%
  -- ROSC 20%
  -- Dosing intervals - 6.1 min
  -- Witnessed arrests 53%
  -- Shockable initial rhythm 23%
  -- On-scene to first drug - 9.5 min

• Significant outcomes
  -- ROSC with shorter on-scene to first drug times (8 vs. 10 min)
  -- No impact of dosing intervals
  -- With respect to early advanced airway Rx, less likely to....
    -- to receive drug early (< 10 min)
    -- to attain ROSC (15.7% vs. 25.4%)
Anti-Arrhythmic Therapy
Bolus Anti-arrhythmic Therapy

-- Lidocaine --

-- Amiodarone --

-- Magnesium --

-- Procainamide --
Lidocaine

• No evidence of beneficial impact
  – Despite decades of recommended use
  – Millions of treated patients

• Now considered an “acceptable alternative”
Amiodarone

• Kudenchuk et al, NEJM 1999 – out-of-hospital
  – vs placebo
  – Pulseless VT / VF
  – No significant difference for survival to hospital discharge

• Dorian P et al, NEJM 2002
  – vs lidocaine
  – Pulseless VT / VF
  – No significant difference for survival to hospital discharge

• Both with higher rates of ROSC & survival to hospital admission
AMIODARONE (vs placebo)
Kudenchuk et al, NEJM 1999

• Prehospital study of patients with shock-resistant VT / VF
• Therapy
  – 3 shocks, ETT, 1 mg epinephrine
  – 300 mg amiodarone (246 patients) or placebo (258 patients)
• Subsequent treatment per standard ACLS
• Results
  – Amiodarone patients -- higher survival to admission (44% vs. 34%)
  – No significant difference for survival to hospital discharge
AMIODARONE (vs lidocaine)

Dorian P et al, NEJM 2002

• Prehospital trial
  – comparing amiodarone with lidocaine
  – 347 patients with refractory VF / VT

• 11% improvement in survival to hospital admission for amiodarone patients

• Less post-countershock asystole in amiodarone group (18% vs 29%)

• NOTE: designed to ID difference for survival to hosp admit / not survival to hosp d/c
Magnesium

• 13 studies demonstrating no benefit

**MAGIC Trail -- representative**

• Prospective, randomized, placebo-controlled, double-blinded clinical trial
• Magnesium sulfate 5 g vs placebo as first line Rx for pre-hospital cardiac arrest
• No improvement in ROSC or survival to hospital discharge

• Consider “niche” application -- potential uses
  – Long QT - related polymorphic VT
  – Toxemia
  – Hyperkalemia
Atropine

• **Cardiac arrest**
  - No value in PEA / asystolic arrest
  - Removed from G2010

• **Compromising bradycardia**
  - Indications unchanged
  - Use early with appropriate doses
Calcium

• Routine administration of calcium does not improve outcome of cardiac arrest.

• “Niche” application -- potential uses
  – Hyperkalemia
  – Certain ingestions
  – Massive blood loss / transfusion
  – Known hypocalcemia

Fibrinolytic Therapy

- Very limited impact
- Poor outcomes
- Indications?
  - All patients vs certain subsets
  - “Niches”
    - Witnessed arrest
    - Pulmonary embolism

Post-Resuscitation Care
Post-Resuscitation Care

• Important addition to cardiac arrest therapy

• General
  – Oxygenation & ventilation
  – Intravascular volume
  – Vasopressor & inotropic support
  – Avoid extremes: oxygen, temperature, etc
  – Seizure control
  – Et cetera……

• Specific
  – Therapeutic (induced) hypothermia
  – Coronary reperfusion
Post-Resuscitation Care

Return of Spontaneous Circulation

Optimize Oxygenation & Ventilation

Follow Commands?

YES

STEMI?

NO

Coronary Reperfusion

YES

Therapeutic Hypothermia

NO

Advanced Critical Care

AHA Guidelines 2010
Post-Resuscitation Care

Oxygen Therapy

• 170 patients resuscitated from cardiac arrest / 77 (45.2%) survived to discharge

• Survival & PaO$_2$ level in first 24 hrs
  – Survivors -- PaO$_2$ 198 mm Hg
  – Non-survivors -- PaO$_2$ 254 mm Hg

• Higher PaO$_2$ levels were significantly associated with...
  – increased hospital mortality (OR 1.439)
  – poor neurological status at D/C (OR 1.485)

Post-Resuscitation Care

Therapeutic Hypothermia

- Hypothermia After Cardiac Arrest Study Group -- Austria

- 275 patients randomized: cooled patients to 32–34°C

- Mortality...
  - 41% (cooled)
  - 55% (non-cooled)

- Good neuro outcome...
  - 55% (cooled)
  - 39% (non-cooled)

NEJM 2002;346:549
Post-Resuscitation Care

Therapeutic Hypothermia

- Prospective study in Australia
- 77 patients randomized: cooled patients to 33°C

- Mortality...
  - 51% (cooled)
  - 68% (non-cooled)

- Good neuro outcome...
  - 49% (cooled)
  - 26% (non-cooled)

NEJM 2002;346:557
Post-Resuscitation Care

Therapeutic Hypothermia

- Meta-analysis: 4 randomized studies
- Number needed to treat to save one life = 7
- Number needed to treat to prevent 1 poor neurologic outcome = 5

Can J Emerg Med 2006;8:329
Therapeutic Hypothermia

Indications

• Nontraumatic cardiac arrest
  – Cardiac-based
  – Sudden event

• Resuscitated
  – Stable
  – Maintained medically

• Unresponsive (& likely intubated)

• Age: 18 to 75 years -- ?????????
Post-Resuscitation Care
Immediate Percutaneous Coronary Intervention

- Prehospital cardiac arrest -- #714 survivors (Paris)
- Retrospective review
- Immediate PCI in ST elevation & non-ST elevation cases

714 survivors → 235 excluded (non-cardiac)

435 to catheterization

Overall 51% survival with PCI vs 31% survival without PCI

134 ST elevation → 128 with at least 1 lesion
74% with PCI → 54% survival

301 no ST elevation → 176 with at least 1 lesion
88% with PCI → 47% survival

Dumas et al, Cardiovasc Interv 2010
Post-Resuscitation Care
Emergent Reperfusion & Therapeutic Hypothermia

- VT / VF survivors
- STEMI demonstrated on 12-lead ECG
- Fibrinolysis vs PCI +/- hypothermia
  - “Survival at 6 months was 54% with 46% demonstrating good neurologic function”
  - “…initially comatose patients survived 51% of hospitalizations with good neurological status in 29%”
  - “…55% of the TH group compared to non-TH group were discharged with good neurological outcome”

Garot Pvet al *Circulation* 2007  
Knafelj et al *Resuscitation* 2007  
Considered safety & feasibility of PCI with simultaneous TH

- 90 cardiac arrest survivors: 20 with PCI during TH & 70 TH only
- Outcomes: malignant dysrhythmia, adverse event, & mortality

No difference in any outcome variable

Very small study -- safely performed

Batista et al, Resuscitation 2010
Resuscitation Centers

• Emerging concept?
• Management of the resuscitated cardiac arrest patient
  – Focused
  – Multidisciplinary
  – Specialist-oriented
• Therapeutic hypothermia
• Early coronary angiography with PCI
• Aggressive critical care support
“Putting It All Together”
“Putting It All Together”

• Reorder the alphabet from ABCs to CABs
• Emphasis on the basic therapies
  – Chest compressions & Defibrillation
• Continued use of advanced therapies
  – Parenteral access
  – Airway management
  – Medications
• Limit therapy-based interruptions in chest compressions
Cardiocerebral Resuscitation

• A “new” concept – 2003 Univ. of Arizona
  – Stressing beneficial Rx
  – Avoiding interruptions in compressions
  – De-emphasizing less beneficial Rx
  – Moving from “A-B-C” to “C-A-B”

• 3 major components
  [1] continuous chest compressions with no early ventilations pre- & post-shock
  [2] delayed endotracheal intubation
  [3] early use of epinephrine
Cardiocerebral Resuscitation

- Out-of-hospital cardiac arrest (#498)
- Comparison of standard Rx (#268) vs cardio-cerebral resuscitation (#230)

Cardio-cerebral resuscitation algorithm
- Chest compressions for 2 minutes - then rhythm analysis
- If “shockable” rhythm (pulseless VT or VF)
  - 1 defibrillation at maximal energy
  - 2 more cycles of compression with defibrillation
  - Oral airway with 100% oxygen by face mask
- If “non-shockable” rhythm (asystole or PEA)
  - Invasive airway placement

Cardiocerebral Resuscitation

• Analysis of subgroups with neuro outcome
  – Witnessed vs unwitnessed
  – Shockable vs non-shockable initial rhythm

• Survivors
  – Unwitnessed & nonshockable – 0 / 167
  – Witnessed & nonshockable – 2 / 108
  – Witnessed & shockable – 60 / 181

Minimally Interrupted Cardiac Resuscitation by EMS for Out-of-Hospital Cardiac Arrest

<table>
<thead>
<tr>
<th>survival-to-hospital discharge</th>
<th>before MICR training</th>
<th>after MICR training</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>1.8% (4/218)</td>
<td>5.4% (36/668)</td>
</tr>
<tr>
<td>witnessed VF</td>
<td>4.7% (2/43)</td>
<td>17.6% (23/131)</td>
</tr>
</tbody>
</table>
Cardiocerebral Resuscitation

*more evidence*……..

- Similar approach – no ETT until 3 cycles of chest compression
- Outcome: survival with neuro status
- #3515 prehospital patients
  - #2491 “standard” ACLS
  - #1024 “CCR”
- Overall survival – 5.8%

Mosier et al, Acad Emerg Med 2010
Cardiocerebral Resuscitation

- **Age-based subgroup survival**

<table>
<thead>
<tr>
<th>Age Group (yr)</th>
<th>ACLS (%)</th>
<th>CCR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 40</td>
<td>3.7</td>
<td>18.8</td>
</tr>
<tr>
<td>40-49</td>
<td>4.1</td>
<td>14.4</td>
</tr>
<tr>
<td>50-59</td>
<td>4.9</td>
<td>11.9</td>
</tr>
<tr>
<td>60-69</td>
<td>6.0</td>
<td>10.2</td>
</tr>
<tr>
<td>70-79</td>
<td>4.2</td>
<td>6.3</td>
</tr>
<tr>
<td>&gt; 80</td>
<td>1.9</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Mosier et al, Acad Emerg Med 2010
## Cardiocerebral Resuscitation vs Standard ALS

- Systematic review: CCR vs ALS
- 13 studies considered – as compared to ALS, CCR performed.....

<table>
<thead>
<tr>
<th>Outcome</th>
<th>CCR [AOR with 95CI]</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Patients - Survival to D/C</td>
<td>1.45 [1.07-1.97]</td>
</tr>
<tr>
<td>All Patients - Neuro Intact Survival</td>
<td>1.25 [1.01-1.55]</td>
</tr>
<tr>
<td>Shockable Rhythm - Survival to D/C</td>
<td>2.03 [1.44-2.86]</td>
</tr>
<tr>
<td>Shockable Rhythm - Neuro Intact Survival</td>
<td>1.47 [0.91-2.36]</td>
</tr>
<tr>
<td>Non-cardiac Cause of Arrest - Survival to D/C</td>
<td>0.68 [0.33-1.39]</td>
</tr>
<tr>
<td>Non-cardiac Cause of Arrest - Neuro Intact Survival</td>
<td>0.63 [0.26-1.51]</td>
</tr>
</tbody>
</table>

Identifying Non-Cardiac Cardiac Arrest

- Difficult to identify non-cardiac causes
  - 31% of 3068 arrest victims had non-cardiac cause
  - Prediction model was difficult to construct
- Difficult to identify underlying cause in PEA
  - 18% had cause ID’ed with specific RX
    - 32% survival compared to 11% in general RX group
  - Trend towards better outcome in specific RX group

Dumas et al, Resuscitation 2012;83:134
Saarinen et al, Resuscitation epub 2011 Dec
Resuscitation in Cardiorespiratory Arrest

- Alphabet change from "ABCs" to the "CABs"
- Basic is awesome / advanced is good & occasionally awesome
- VT / VF arrests
  - Most awesome chest compressions
  - Limit interruptions
  - Early defibrillation
- PEA / asystole arrests
  - Chest compressions without interruption
  - IVF & medications
  - Airway management
  - Beware the exceptions to the "CAB approach"