STRATEGIES TO IMPROVE SHOCK SUCCESS
NTI 2015

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OBJECTIVES

• Understand the prevalence of sudden cardiac arrest (SCA) rhythms and current survival rates

• Describe current approaches to improving resuscitation efforts

• Describe the key goals for CPR performance

• Describe the key strategies for improving defibrillation performance

• Describe how the relationship between defibrillation and CPR impacts overall resuscitation efforts
Are we evaluating cardiac arrest resuscitation performance from every aspect?

» How do you define SCA? VT/VF, PEA, Asystole?

» How do you define defibrillation success?
  » Only termination of VT/VF?
  » Or based on what the heart does after termination of VT/VF?

» Do you know your hospital SCA survival rates?

» Are you systematically evaluating your resuscitation performance?

“If I had an hour to solve a problem I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions.” - Albert Einstein
CURRENT ARREST RHYTHMS AND SURVIVAL DATA

**OHCA**
- VT/VF
- 19%-23%²
- Avg. survival rate is 16% (all rhythms)³
- Large regional variability (year, race, country)

**IHCA**
- VT/VF
- 32%⁵
- Avg. survival rate is 18% (all rhythms)³
- Variation among facilities, average has not changed

Seattle survival rate for witnessed VF is at 62%⁴

* 10% unknown by documentation
SCA

IMPROVING RESUSCITATION

ACLS drugs

» Epinephrine- No strong supporting data\(^6\) - combination of Epi, Vasopressin and Steroid (?)

» Amio or Lido for persistent or recurring VT/VF- ALPS study in 2015

CPR is more important than ever

» Shift from VT/VF to more PEA / asystole

» AHA Guidelines - 2 min CPR cycle after each failed shock

Defibrillation success is more important than ever

» AHA Guidelines - 2 min CPR cycle after each failed shock

» VT/VF- metabolically draining

» CPP (coronary perfusion pressure)

» CPR pauses

Prolonged duration of resuscitation is associated with higher mortality.\(^7\)
What do the 2010 AHA Guidelines\textsuperscript{8} and 2013 AHA Consensus Statements on IHCA say?\textsuperscript{9}

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Class</th>
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<tbody>
<tr>
<td>Depth ≥2 inch</td>
<td>IIa</td>
</tr>
<tr>
<td>Rate ≥100 per min</td>
<td>IIa</td>
</tr>
<tr>
<td>Full recoil</td>
<td>IIa</td>
</tr>
<tr>
<td>Minimize interruptions in CPR</td>
<td>IIa</td>
</tr>
<tr>
<td>50/50 duty cycle</td>
<td>IIb</td>
</tr>
<tr>
<td>Avoid excessive ventilation</td>
<td>IIb and IIa</td>
</tr>
<tr>
<td>30:2 or &lt; 12 breaths/min.</td>
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<tr>
<td>Minimal chest rise</td>
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</table>

Challenges

» Many are not meeting these goals\textsuperscript{10}
» Many are not measuring performance
» Real-time CPR feedback technology alone doesn’t appear to be the answer\textsuperscript{11-14}
» But feedback combined with debriefing has demonstrated improvement\textsuperscript{15}
What do the 2010 AHA Guidelines say?\textsuperscript{16}

- Biphasic is more effective and safer than monophasic
- No specific biphasic waveform is superior
- Escalate defibrillation energy
- Physio Control: 200J-300J-360J

What has the clinical research shown?

- There is room to improve defibrillation probability\textsuperscript{56-63}
- Some patients are more “difficult-to-defibrillate”\textsuperscript{40,41}
- Biphasic shocks at 360 joules can improve defibrillation probability\textsuperscript{41,43}
- No one factor of energy is more important to defibrillation probability\textsuperscript{64-68}
  - Energy = Current x Voltage x Time

SCA
DEFIBRILLATION PERFORMANCE

Biphasic Peak Current
Monophasic Peak Current
40% more peak current

Current (amps)

Time (msec)

40
30
20
10
0
-10
-20
0
5
10
15
20
DEFIBRILLATION PERFORMANCE
FAILED SHOCKS ARE COSTLY
Each failed shock means…

» Longer CPR duration
» Impacts CPP (coronary perfusion pressure)
» Introduce more potential for compression pauses
» Longer resuscitations are associated with lower survival rates\textsuperscript{17,18,19}

After the first shock fails…

» The probability of success for subsequent shocks gets worse, not better
» This is why we have to escalate energy to a bigger shock dose
Compression pause impact on Coronary Perfusion Pressure (CPP)

- CPP keeps the myocardium “primed”
- Normal CPP=60 mmHg, minimum CPP >20mmHg recommended by the AHA during CPR
- Most using arterial diastolic or EtCO2 as a surrogate guide
- After a compression pause it can take up to 90 sec to re-establish CPP
More potential for compression pauses

» Interruptions in chest compressions have been shown to reduce survival and neurologic outcome from cardiac arrest\textsuperscript{20-22}

» Prolonged pre-shock pauses may impact termination of VT/VF, but they do impact survival\textsuperscript{23–28}

» Prolonged pre-shock and post-shock pauses associated with AED analysis have been shown to reduce survival from SCA\textsuperscript{29}

» Prolonged pauses not related to shocks have been shown to reduce survival from SCA\textsuperscript{33}
SCA
THE COST OF FAILED SHOCKS

Peri-shock pauses

» DEFINE: Pauses before and after a shock

» Median pre-shock + post-shock (peri-shock) pause for manual shocks = 24 seconds for manual defibrillation and 42 sec for AED shocks\textsuperscript{31}

» ROC data- significant relationships between peri-shock pause and survival to discharge from OHCA\textsuperscript{32}

>25 sec peri-shock pause in compressions
Non-peri-shock pauses

» DEFINE: Pauses that are not associated with a shock

» 39% of the longest pauses in chest compressions (24 sec avg.) are non-peri-shock pauses (n=319)\(^{33}\)

» Avoiding long pauses for interventions other than defibrillation may be more important

> 37 sec non-peri-shock pause in compressions
WHY DO SHOCKS FAIL?

THE SCIENCE OF DEFIBRILLATION
SCA
DEFIBRILLATION SCIENCE

Goal of the shock

» Extend refractoriness of each cell (complete depolarization, no longer excitable)
» Voltage gradient change must envelop all of the heart
» SHOCK FAILURE occurs at the weakest point of the field$^{72,73}$

VF is a mixture of cell states

Excitable cells
Relative refractory cells
Absolute refractory cells

Transmembrane Potential

Depolarization Zone

-90mV

Absolutely Refractory
Relatively Refractory
Excitable
How can we optimize defibrillation success?

1. Optimize coverage of the electrical field - Relates more to improving probability of VT/VF termination

2. Increase strength of the electrical field - Relates more to improving probability of VT/VF termination

How can we optimize defibrillation within the resuscitation process?

3. Faster time to shock - Relates more to the heart after the shock

4. Minimize CPR pauses - Relates more to the heart after the shock
OPTIMIZE ELECTRICAL FIELD COVERAGE
PAD PLACEMENT
Myocardial “sandwich”
- Electrical energy field should envelope the entire fibrillating myocardium
- Pad placement affects current distribution in the myocardium\textsuperscript{54,55}

Double sequential defibrillation (two “myocardial sandwiches”)
- Uses 4 pads instead of 2 pads
- The weakest point of the Ant-Lat electrical field is filled in by the A-P electrical field
- Off-label use, no clinical studies, only case studies

Pad placement
- Among lay-users and professionals, pad placement often varies by more than 5 cm\textsuperscript{49-53}
- The effects of these variations have not been studied
Pad placement matters

- NEW research - 2014 AHA Scientific Session
- Pads were attached at 3 different symmetric positions
- Inside pad edges placed 3%, 7%, and 11% of the way around the circumference of the chest from the midline of the sternum
- Evaluated 3 different shock energies at each pad position
  - 150J
  - 200J
  - 360J

3 different pad placements

- Position #1 (3% from midline sternum)
- Position #2 (7% from midline sternum)
- Position #3 (11% from midline sternum)
Pad placement matters

- Differences in electrode pad placement, which are well within user-to-user variation, significantly affected shock efficacy (p<0.02)

- Suboptimal pad placement was overcome by using a higher defibrillation shock dose (p<0.01) 36
HOW CAN WE IMPROVE SHOCK SUCCESS?

✓ 1. OPTIMAL ELECTRICAL FIELD COVERAGE (PAD PLACEMENT)
2. INCREASE STRENGTH OF THE ELECTRICAL FIELD (SHOCK ENERGY 360J)
3. FASTER TIME TO SHOCK
4. MINIMIZE CPR PAUSES
FIRST, DO SOME PATIENTS NEED MORE ENERGY?

DIFFICULT-TO-DEFIBRILLATE PATIENTS
Not all patients convert at energy levels up to 200 joules

» The 2010 AHA Guidelines state that biphasic first shock efficacy is >90%\textsuperscript{35}

» FACT: Only 8 of 27 of published studies report efficacy >90%\textsuperscript{56-63} (see appendix)
  » Some report first shock success rates ≤70%

» FACT: 11 of the 27 studies reported on all-shock success (see appendix)
  » The pooled efficacy was only 78%

» FACT: 7 of those studies reported on energy protocols at ≤ 200J (see appendix)
  » Pooled efficacy of these shocks was only 67% (1/3 of shocks failed)
A subset of patients account for the majority of failed shocks

- Koster – Large group of cardiac arrest patients with recurrent VF (n=465)\(^{38}\)
  - 11% were labeled “difficult-to-defibrillate” and required multiple shocks for recurrent VF
  - All were eventually defibrillated at 360J

- Walker – Largest set of cardiac arrest data ever collected on biphasic waveforms (n=863 pts)\(^{37}\)
  - 5-10% were labeled “difficult-to-defibrillate” and accounted for the majority of failed shocks
What makes some patients more difficult to defibrillate?

» From an external defibrillation standpoint, no clinical answer yet
  » Not patients with high impedance
  » Not much data to support body cavity size
  » Not necessarily down time- acidosis effect on action potential
  » Not necessarily degree of ischemia or scar tissue

Electrophysiology perspective

» EPs use “high energy” ICDs (25% more shock energy than standard ICDs)
  » Dilated LV, class III CHF, very low EF%
  » Hypertrophic Cardiomyopathy
  » Class III Antiarrhythmic- Amiodarone (metabolite)
STRENGTHEN THE ELECTRICAL FIELD
ESCALATING TO 360 JOULES
DO YOU KNOW WHAT YOUR DEFIBRILLATION ENERGY PROTOCOLS ARE FOR CARDIAC ARREST?

1. YES
2. NO
Published Clinical Performance Data
Cardiac Arrest Patients Treated with Biphasic Shocks

Cumulative Patients Studied

- Patients treated with Physio-Control biphasic shocks
- Patients treated with all other biphasic shocks

(as of December 2013)
What do the AHA Guidelines say?

» “Evidence from 1 well-conducted randomized trial (LOE 1) and 1 other human study (LOE 2) employing BTE waveforms suggested that higher energy levels are associated with higher shock-success rates.”

What has the clinical data shown?

» Increasing shock energy increases defibrillation probability

» No clinical data to indicate that the benefit of escalating energy stops at 150 joules, 200 joules or 300 joules

» What about 360 joules?
**Defibrillation Energy Matters**

**Escalating to 360 joules**

- Stiell study: Only randomized, triple-blinded controlled study (n=221 pts) comparing energy dosing protocols in cardiac arrest.
- Compared 150J-150J-150J or 200J-300J-360J for OHCA pts. 24% of pts received shocks at 360J.

### Rate of VF Termination

<table>
<thead>
<tr>
<th></th>
<th>Single shock patients</th>
<th>Multi-shock patients</th>
<th>Rate of VF Termination</th>
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</thead>
<tbody>
<tr>
<td>Fixed lower energy</td>
<td>71.2% (+11.3%)</td>
<td>Escalating higher energy</td>
<td>82.5%</td>
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<tr>
<td>(n=292)</td>
<td></td>
<td>(n=206)</td>
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</table>

**P = 0.027**

### Termination to Organized Rhythm

<table>
<thead>
<tr>
<th></th>
<th>Single shock patients</th>
<th>Multi-shock patients</th>
<th>Termination to Organized Rhythm</th>
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</thead>
<tbody>
<tr>
<td>Fixed lower energy</td>
<td>24.7% (+11.9%)</td>
<td>Escalating higher energy</td>
<td>36.6%</td>
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<tr>
<td>(n=229)</td>
<td></td>
<td>(n=154)</td>
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</table>

**P = 0.035**
Escalating to 360 joules

» Walker study—largest set of cardiac arrest data ever collected on biphasic waveforms (n=863 pts)
» Compared 200J-200J-360J vs. 200J-300J-360J protocols
» Reported an increase in shock success with increasing energy in a subset of patients who received shocks at each energy level (n=236 pts) 

Defibrillation Probability Increases with Each Energy Dose

% Cumulative success

- Biphasic 200J: 82%
- Biphasic 300J: 86%
- Biphasic 360J: 90%
HOW CAN WE IMPROVE SHOCK SUCCESS?

1. OPTIMAL ELECTRICAL FIELD COVERAGE (PAD PLACEMENT)
2. INCREASE STRENGTH OF THE ELECTRICAL FIELD (SHOCK ENERGY 360J)
3. FASTER TIME TO SHOCK
4. MINIMIZE CPR PAUSES
SCA
TIME TO SHOCK MATTERS

Get a shock on board ASAP

» Time to successful shock is a determinant of survival\textsuperscript{44-48}
» At 5 min in SCA = 50\% survival rate without intervention\textsuperscript{40}
» Get With The Guidelines (GWTG) data showed hospital time-to-defibrillation varied wildly (18.3\% ≥ 3 min)\textsuperscript{71}

Time spent in VT/VF

» VT/VF is very metabolically draining (3 phase model)

<table>
<thead>
<tr>
<th>Electrical Phase$^{41}$</th>
<th>Circulatory Phase$^{41}$</th>
<th>Metabolic Phase</th>
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</thead>
<tbody>
<tr>
<td>3-5 min</td>
<td>5-10 min</td>
<td></td>
</tr>
</tbody>
</table>

» Treat with defibrillation
» Stop tachy arrhythmia to increase survival

» Treat with CPR and defibrillation
» Termination of VT/VF is a necessity, but not the only requirement for survival
CPR pauses

Summary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>CPR needed</td>
<td>13:49</td>
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<tr>
<td>Longest compression pause</td>
<td>0:27</td>
</tr>
<tr>
<td>Compression count</td>
<td>1347</td>
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<tr>
<td>Pauses over 10 sec</td>
<td>2</td>
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</tbody>
</table>

If shocks were delivered, they would appear at the end of the report showing:

<table>
<thead>
<tr>
<th>Shock</th>
<th>Time</th>
<th>Energy</th>
<th>Pre-shock CPR pause</th>
<th>Post-shock CPR pause</th>
</tr>
</thead>
<tbody>
<tr>
<td>⚡1</td>
<td>0:23</td>
<td>360J</td>
<td>--</td>
<td>0:02</td>
</tr>
<tr>
<td>⚡2</td>
<td>10:42</td>
<td>360J</td>
<td>0:00</td>
<td>0:00</td>
</tr>
<tr>
<td>⚡3</td>
<td>15:02</td>
<td>360J</td>
<td>0:15</td>
<td>0:04</td>
</tr>
</tbody>
</table>
SCA
MINIMIZE CPR PAUSES

What about shocking during mechanical chest compression?

» Completely removing the pre-shock pause

» 2014 AHA Scientific Session- impact of shock timing during LUCAS® on shock success

» VF termination was not affected by the duration of pre-shock pauses (n=153 cases)

» 2015 CIRC data- pre-shock pause effects on termination of VF with mechanical CPR with AutoPulse

» VF termination was not affected by the duration of pre-shock pauses (n=417, shocks=1,618)
POP SURVEY

DO YOU ROUTINELY RECEIVE PERFORMANCE FEEDBACK ON CPR PAUSES DURING CODES?

1. YES
2. NO
HOW CAN WE IMPROVE SHOCK SUCCESS?

✓ 1. OPTIMAL ELECTRICAL FIELD COVERAGE (PAD PLACEMENT)
✓ 2. INCREASE STRENGTH OF THE ELECTRICAL FIELD (SHOCK ENERGY 360J)
✓ 3. FASTER TIME TO SHOCK
✓ 4. MINIMIZE CPR PAUSES
✓ 5. HANDS-ON DEFIBRILLATION?
SCA
HANDS-ON DEFIBRILLATION

Is hands-on defibrillation safe?

» Goal: reduce peri-shock pauses, increase CC fraction
» 1 Joule of energy transfer can cause VF
» Lemkin et al. 2014. Resuscitation
  » Current leaked all over cadavers
  » “posses real risk to rescuers”
» Thomsen et al. 2014 AHA Scientific Sessions
  » Sub-threshold current transfer with 360 joules- wearing “insulated” gloves
» Other reports of shocked rescuers, but not life-threatening

Bottom line: It’s still not recommended

» For now, keep the “I’m clear, you’re clear, we’re clear, the people upstairs are clear…. “
» Keep the focus on shortening compression pauses
<table>
<thead>
<tr>
<th>SCA survival rates</th>
<th>CPR Performance</th>
<th>Defibrillation Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Cardiac arrest survival rates remain low</td>
<td>✓ More important than ever</td>
<td>✓ Pad placement may be more important to defibrillation probability than previously thought</td>
</tr>
<tr>
<td>✓ Improvements in cardiac arrest resuscitation require simultaneous improvements in multiple aspects of resuscitation, not just one</td>
<td>✓ Clear, established performance goals exist</td>
<td>✓ Escalating to biphasic defibrillation energy to 360 joules can improve defibrillation probability</td>
</tr>
<tr>
<td></td>
<td>✓ Good quality CPR can improve survival</td>
<td>✓ Limiting CPR pauses probably impacts survival more than defibrillation probability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>✓ Hands-on defibrillation is still not ready to be recommended</td>
</tr>
</tbody>
</table>


4 Cardiac Arrest Survival in Seattle and King County. 2014. Published statistics.


BIBLIOGRAPHY

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<table>
<thead>
<tr>
<th>Shock Energy</th>
<th>Percentage</th>
<th>Reference</th>
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<tbody>
<tr>
<td>100 and 150J</td>
<td>61%</td>
<td>[Heartsine, Philips]*</td>
</tr>
<tr>
<td>120J</td>
<td>67%</td>
<td>[Prehosp Emerg Care. 2004;8:388-92]</td>
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<td>120J</td>
<td>88%</td>
<td>[ZOLL]</td>
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<td>130J</td>
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<td>70%</td>
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<tr>
<td>200J</td>
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