CPR and Circulatory Adjuncts

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Objectives

• Briefly discuss physiology of blood flow during CPR
• Discuss hemodynamics of CPR
• Discuss mechanical adjuncts for improving blood flow during CPR
Advanced life support (ACLS) is a group of therapies intended to reverse sudden death – which is death in the midst of life in patients with relatively intact organ systems.

ACLS is not intended to reverse a loss of vital signs at the end of the dying process. Its use in that setting is without scientific basis.
# Survival After CPR in 3 Television Series

<table>
<thead>
<tr>
<th>Series</th>
<th># of Occurrences per Episode</th>
<th>Short-Term Survival</th>
<th>Survival to Discharge</th>
<th>Death in Hospital</th>
<th>Outcome Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicago Hope</td>
<td>.5</td>
<td>7 (64)</td>
<td>4 (36)</td>
<td>3 (27)</td>
<td>0</td>
</tr>
<tr>
<td>ER</td>
<td>1.24</td>
<td>21 (68)</td>
<td>NA*</td>
<td>3 (10)</td>
<td>18 (58)</td>
</tr>
<tr>
<td>Rescue 911</td>
<td>.36</td>
<td>18 (100)</td>
<td>18 (100)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>.62</strong></td>
<td><strong>46 (77)</strong></td>
<td><strong>22 (37)</strong></td>
<td><strong>6 (10)</strong></td>
<td><strong>18 (30)</strong></td>
</tr>
</tbody>
</table>

*Not applicable. ER deals only with events in the Emergency Department.

Real Out of Hospital Cardiac Arrest Outcome Data

- VF arrest: 10-25% survival to hospital admission
- PEA arrest: 2-8% survival to hospital admission
- Asystolic arrest: 0-2% survival to hospital admission

Overall survival rate for OOHCA averages 6.4%
Physiology of Blood Flow During CPR

Cardiac Pump and Thoracic Pump Theories
Physiology of Forward Flow: Cardiac Pump Model

- Heart is compressed between sternum and vertebral column
- Blood is squeezed from the heart into the arterial circulation
- Heart refills with relaxation of the compression
- Coronary arteries are perfused as if it is a normal functioning circulation with normal valves
- There is essentially no change in intrathoracic pressure during compressions
Physiology of Forward Flow: Thoracic Pump Model

- Chest compressions cause rise in intrathoracic arterial vasculature pressures
- No change in intrathoracic venous pressures due to high compliance of system
- High arterial-venous gradient causes blood flow out of thorax
Mechanisms of Forward Flow: Thoracic Pump

• With relaxation of chest compression, fall in intrathoracic pressure causes venous blood to return into thorax
• As intrathoracic pressure falls, arterial blood returns retrograde into coronary arteries
Hemodynamic Considerations During CPR
Coronary Perfusion Pressure

CPP = AoDP - RADP

AoDP: aortic diastolic pressure
RAP: right atrial diastolic pressure
CPP vs Return of Spontaneous Circulation (ROSC)

Paradis NA, et.al., JAMA 1990;
263:1106-1113
Perfusion During CPR
CPR: Force vs Flow

Ditchey et al 1982 Dog Model

Blood Flow (% of Control)

Carotid
Coronary

Compression Force (pounds)

40 60 80 100 120 140

p<0.01 p<0.01 p<0.01 p<0.01

p<0.01 p<0.01
Interruptions in CPR

CPP

TIME
Hyperventilation-Induced Hypotension During CPR: Breaths/Min

Mean Intrathoracic Pressure

Coronary Perfusion Pressure

PaCO2

Aufderheide TP, et.al., Circulation 2004; 109:1960-65

Survival
Summary of CPR Hemodynamics

• Improving CPP during CPR correlates with improved ROSC and survival
• CPR creates little pressure gradient for flow
• Interruptions in CPR are harmful to flow
• Hyperventilation is harmful to flow
Circulatory Adjuncts
Pneumatic Vest CPR

Vest CPR

Manual CPR

Vest

Circumferential compression

Pneumatic System

ECG

Defibrillators

ECG

Point compression
Autopulse

• Improved CPP and aortic pressure in animal models\(^1\)
• Improved arrival to ED with spontaneous pulse and survival to hospital discharge vs. standard CPR\(^2\)
• Worsened neurologic outcomes and trended towards worsening survival\(^3\)
• May have greater significance for PEA subgroup
• Remains controversial

2. Ong, et.al, JAMA 2006; 295: 2629
Interposed Abdominal Compression CPR (IAC-CPR)
Interposed Abdominal Compression CPR (IAC-CPR)

• Improved ROSC and long-term survival in 3 studies\(^1\)\(^-\)\(^3\)
• Improves CPP and CBF in animal studies
• May have added benefit in PEA/pseudo-PEA and asystole patients\(^2\)

1. Sack, et.al., JAMA 1992; 267:379
2. Sack, et.al., Circulation 1992; 86:1692
LifeStick™ CPR

Cardiac filling

- Abdominal compression
- Sternal decompression

Cardiac ejection

- Abdominal decompression
- Sternal compression
Active Compression-Decompression CPR (ACD-CPR)

• Increased myocardial and cerebral perfusion in animal models
• Rate of hospital discharge without neurologic impairment and 1 year survival improved with ACD-CPR vs standard*

*Plaisance P, et.al., NEJM 1999, 341:569-75
ResQPUMP

- 9/17 (ACD-CPR) vs 2/7 (standard CPR)
- 1 yr survivors had asystole or PEA
Impedance Threshold Device (ITD; ResQPod)

- Impedes entry of air into lungs during upstroke of CPR without impeding normal positive pressure ventilations.
- Creates relative negative intrathoracic pressure and augments venous return.
Impedance Threshold Device (ITD)
Impedance Threshold Device (ITD)

- Prospective, double blind trial randomized to receive ITD or sham ITD for OOHCA
- 12 ITD and 10 sham with invasive monitoring in field via femoral artery
- MAP 85mmHg in ITD group, 43mmHg in sham
- Other characteristics without difference (EMS, demographics, witnesses, etc)

Impedance Threshold Device (ITD)

- 2nd study with 114 ITD pts, 116 sham devices
- If PEA at anytime during resuscitation
  - ICU admissions 41% vs 20%
  - 24 hr survival 27% vs 11%
  - n=49 for ITD, n=56 for sham
- No differences for the VF, asystole subgroups

Aortic Balloon Counterpulsation (IABP)

- Inflating an aortic balloon during CPR would increase AoDP and CPP
- 10/10 animals with ROSC in IABP group vs 1/5 with epinephrine alone
- No large human trials to date, some case reports
Cardiopulmonary Bypass

• “assume control” of circulatory process until medical etiology of cardiac arrest is repaired
• Several studies done in Europe and Japan
• Not ready for prime time-labor intensive, expertise issues, etc
Cardiac Synchronization Technology (CST)

- Synchronizes chest compressions with residual cardiac activity during Pseudo-PEA and PEA arrest
- There is an inherent delay between the electrical signal in the heart and the resultant aortic pressure wave generated by a contraction which defines the Pulse Arrival Time (100msec)
Cardiac Synchronization Technology (CST)

Arterial Blood Pressure:
- Mode 1 – full systole
- Mode 2 – 1st half systole
- Mode 3 – 2nd half systole
- Mode 4 – Diastole

Chest Displacement:

(time)
Cardiac Synchronization Technology (CST)
Conclusions

• Circulatory Adjuncts are being developed to mechanically improve important resuscitation parameters and outcomes from cardiac arrest
• Limited improvements in outcomes
• Mechanical advantages may only be beneficial to a limited degree-likely need molecular solutions
Questions?

Thanks!