Mechanical CPR versus Manual CPR for cardiac arrest

7th International Spark of Life
Australian Resuscitation Council
May 2 2009
Conflict of Interest

• Laurie Morrison
  – Grants from Zoll for unrelated studies completed in 2004
  – Zoll owns majority shares in Revivant (makes Autopulse)
Mechanical CPR Devices

- Thumper
- Vest CPR
- Autopulse
- Lucas
- Lifebelt
Michigan Instruments
“Thumper”
Gas Driven Piston

• Introduced in 1963
• First automated CPR device in wide use.
• Began as a compression-only device and later has ventilator added.
Incremental Change over Time

- Thumper Model 1007
  - 1998 - introduced in Japan.
  - 1999 - Introduced to U.S.
  - 2005 – Introduced to Europe
- High-impulse piston movement
- Built-in ventilator
- Faster deployment
- Adjustable to patient size
Vest CPR Device
Vest CPR
Vest CPR – Optimize Intrathoracic Pressure

- Laboratory Data
  Normal Flow to Heart, Brain
  \( \uparrow \) 24 hr Survival (\( p<0.01 \))
  Halperin et al, Circ 1986

- Human CPP (\( \text{N}=15 \))
  Vest: \( 23 \pm 11 \text{ mm Hg} \)
  Manual: \( 15 \pm 8 \) (\( p<0.003 \))
  Halperin, et al. NEJM; 1993
AutoPulse

• A cardiac support pump
• Uses circumferential load-distributing band
  – Animal models show that the load-distributing band increases cardiac output during CPR compared to manual CPR.
• What does the AutoPulse do?
  – Consistent depth + rate for chest compressions
  – Chest compressions with no interruptions
Active Compression Decompression CPR

Metronome

Force Gauge

Suction Cup

Handle

Slide courtesy of Keith Lurie, MD
LUCAS Chest Compression System

On/off knob
Patient strap
Release Ring
Support leg
Claw Lock
Hood
Hose attachment
Bellows
Height adjustment handle
Suction cup
Air hose
Back plate
LUCAS unique connector
Pressure pad
Knob positions:
- ADJUST (1)
- LOCK (2)
- ACTIVE (3)
Lifebelt
LifeBelt

- Uses a lever to gain mechanical advantage
- Has a gage to help rescuer know how hard to push
- Includes a circumferential belt around the chest
LifeBelt

- Pig study suggests it may improve blood flow over standard manual CPR.
- Inexpensive compared with AutoPulse, LUCAS, or Thumper.
- May combine with AEDs in public locations.
Objective

• To assess the effectiveness of mechanical chest compression versus manual chest compression in patients with cardiac arrest treated with CPR
Search Results

• Citations
  – 1100 MEDLINE, EMBASE, Science Citation index
  – 62 Cochrane Central
  – 32 Clinicaltrials.gov
  – 18 Biotechnology and Bioengineering abstracts
  – 18 Clinicaltrials.com
  – 8 Hand search of included articles

• TOTAL 1238
Relevance Review

- 2 authors (Steve Brooks and Blair Bigham)
- Independent, hierarchical review using apriori inclusion criteria
- Removal of duplicates
- 14 articles pending full review

1238 titles

↓

140 abstracts

↓

43 full articles
Agreement for Relevance

- Kappa statistic
  - Titles 0.68 “Good”
  - Abstracts 0.39 “Fair”
  - Full Articles 1.0 “Perfect”
Included Studies

• Dickinson 1998
• Hallstrom 2006
• Halperin 1993
• Taylor 1978
Data Abstraction

• 2 authors
  – Independent data abstraction
  – Standardized data abstraction tool
  – Discrepancies resolved by consensus
  – Consensus pending
<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Population</th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dickinson 1998</td>
<td>17</td>
<td>Out-of-hospital</td>
<td>PISTON “Thumper” 80/min</td>
<td>Protocol Not Reported 80/min Audio promt</td>
</tr>
<tr>
<td>Quasi-RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hallstrom 2006</td>
<td>767</td>
<td>Out-of-hospital</td>
<td>LDB “Autopulse” 80/min 15:3 second pause</td>
<td>3 CPR protocols 100/min</td>
</tr>
<tr>
<td>Cluster RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halperin RCT</td>
<td>34</td>
<td>In-hospital</td>
<td>Pneumatic Vest ? ? 5:?</td>
<td>Protocol Not reported High dose epi use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Failed standard”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taylor RCT</td>
<td>50</td>
<td>In-hospital</td>
<td>PISTON ? 60/min 5:1</td>
<td>Not reported</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“prolonged standard”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>N</td>
<td>Population</td>
<td>Intervention</td>
<td>Control</td>
</tr>
<tr>
<td>---------------</td>
<td>----</td>
<td>----------------</td>
<td>-----------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Dickinson</td>
<td>17</td>
<td>Out-of-hospital</td>
<td>PISTON “Thumper” 80/min</td>
<td>Protocol Not Reported 80/min Audio promt</td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quasi-RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hallstrom</td>
<td>767</td>
<td>Out-of-hospital</td>
<td>LDB “Autopulse” 80/min</td>
<td>3 CPR protocols 100/min</td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td>15:3 second pause</td>
<td></td>
</tr>
<tr>
<td>Cluster RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halperin</td>
<td>34</td>
<td>In-hospital</td>
<td>Pneumatic Vest ? ? 5:?</td>
<td>Protocol Not reported High dose epi use</td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td>“Failed standard”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taylor</td>
<td>50</td>
<td>In-hospital</td>
<td>PISTON ? 60/min 5:1</td>
<td>Not reported</td>
</tr>
<tr>
<td>1978</td>
<td></td>
<td>“prolonged standard”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>N</td>
<td>Population</td>
<td>Intervention</td>
<td>Control</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----</td>
<td>------------------</td>
<td>-------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Dickinson 1998 Quasi-RCT</td>
<td>17</td>
<td>Out-of-hospital</td>
<td>PISTON “Thumper” 80/min</td>
<td>Protocol Not Reported 80/min Audio promt</td>
</tr>
<tr>
<td>Hallstrom 2006 Cluster RCT</td>
<td>767</td>
<td>Out-of-hospital</td>
<td>LDB “Autopulse” 80/min 15:3 second pause</td>
<td>3 CPR protocols 100/min</td>
</tr>
<tr>
<td>Halperin 1993 RCT</td>
<td>34</td>
<td>In-hospital</td>
<td>Pneumatic Vest ?</td>
<td>Protocol Not reported High dose epi use</td>
</tr>
<tr>
<td>Taylor 1978 RCT</td>
<td>50</td>
<td>In-hospital</td>
<td>PISTON ? 60/min 5:1</td>
<td>Not reported</td>
</tr>
<tr>
<td>Study</td>
<td>N</td>
<td>Population</td>
<td>Intervention</td>
<td>Control</td>
</tr>
<tr>
<td>---------------</td>
<td>----</td>
<td>---------------------</td>
<td>-------------------------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80/min Audio promt</td>
</tr>
<tr>
<td>Hallstrom 2006 Cluster RCT</td>
<td>767</td>
<td>Out-of-hospital</td>
<td>LDB “Autopulse” 80/min 15:3 second pause</td>
<td>3 CPR protocols 100/min</td>
</tr>
<tr>
<td>Halperin 1993 RCT</td>
<td>34</td>
<td>In-hospital “Failed standard”</td>
<td>Pneumatic Vest ? ? 5:?</td>
<td>Protocol Not reported High dose epi use</td>
</tr>
<tr>
<td>Taylor 1978 RCT</td>
<td>50</td>
<td>In-hospital “prolonged standard”</td>
<td>PISTON ? 60/min 5:1</td>
<td>Not reported</td>
</tr>
<tr>
<td>Study</td>
<td>N</td>
<td>Population</td>
<td>Intervention</td>
<td>Control</td>
</tr>
<tr>
<td>----------------</td>
<td>----</td>
<td>-----------------</td>
<td>--------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>Dickinson 1998</td>
<td>17</td>
<td>Out-of-hospital</td>
<td>PISTON “Thumper” 80/min</td>
<td>Protocol Not Reported 80/min Audio prompt</td>
</tr>
<tr>
<td>Quasi-RCT</td>
<td></td>
<td></td>
<td>LDB “Autopulse” 80/min 15:3 second pause</td>
<td>3 CPR protocols 100/min</td>
</tr>
<tr>
<td>Cluster RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halperin 1993</td>
<td>34</td>
<td>In-hospital</td>
<td>PISTON ? ? 60/min   5:1</td>
<td>Not reported</td>
</tr>
<tr>
<td>RCT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taylor 1978</td>
<td>50</td>
<td>In-hospital</td>
<td>PISTON ? ? 60/min 5:1</td>
<td>Not reported</td>
</tr>
<tr>
<td>Study</td>
<td>N</td>
<td>Population</td>
<td>Intervention</td>
<td>Control</td>
</tr>
<tr>
<td>---------------</td>
<td>-----</td>
<td>------------------</td>
<td>------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>80/min</td>
<td>80/min Audio prompt</td>
</tr>
<tr>
<td>Hallstrom 2006 Cluster RCT</td>
<td>767</td>
<td>Out-of-hospital</td>
<td>LDB “Autopulse” 80/min 15:3 second pause</td>
<td>3 CPR protocols 100/min</td>
</tr>
<tr>
<td>Halperin 1993 RCT</td>
<td>34</td>
<td>In-hospital “Failed standard”</td>
<td>Pneumatic Vest ? ?</td>
<td>Protocol Not reported High dose epi use</td>
</tr>
<tr>
<td>Taylor 1978 RCT</td>
<td>50</td>
<td>In-hospital “prolonged standard”</td>
<td>PISTON ? 60/min 5:1</td>
<td>Not reported</td>
</tr>
</tbody>
</table>
Quality Assessment

• 2 authors (SCB and BB)
• Modified Thomas Quality Assessment Tool for Quantitative Studies

<table>
<thead>
<tr>
<th>Study Name and design</th>
<th>Selection Bias</th>
<th>Allocation Bias</th>
<th>Baseline Confounder</th>
<th>Blinding of Outcome Assessors</th>
<th>Follow-up rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dickinson 1998 Quasi-RCT</td>
<td>WEAK</td>
<td>MODERATE</td>
<td>WEAK</td>
<td>WEAK</td>
<td>STRONG</td>
</tr>
<tr>
<td>Hallstrom 2006 Cluster RCT</td>
<td>WEAK</td>
<td>STRONG</td>
<td>WEAK</td>
<td>WEAK</td>
<td>STRONG</td>
</tr>
<tr>
<td>Halperin 1993 RCT</td>
<td>WEAK</td>
<td>MODERATE</td>
<td>WEAK</td>
<td>WEAK</td>
<td>WEAK</td>
</tr>
<tr>
<td>Taylor 1978 RCT</td>
<td>WEAK</td>
<td>MODERATE</td>
<td>WEAK</td>
<td>WEAK</td>
<td>STRONG</td>
</tr>
</tbody>
</table>
Data Synthesis

- Random effects model used to calculate pooled estimate of risk
  - Variability in design, population, intervention and control
Types of Outcome Measures

• Primary
  – Survival to hospital discharge with good neurologic function equivalent to a CPC 1 or 2 as measured with any validated neurological function scale

• Secondary
  – Survival at one year, survival at 6 months, survival to hospital admission, ROSC

• Adverse effects
  – Rate of injury caused by machine in survivors, EMS on-scene time interval, 911 call to first shock time interval, scene arrival to ROSC time interval
Primary Outcome: Survival to hospital discharge with good neurological outcome

- Only one study reported primary outcome
- Hallstrom 2006
  - Mechanical: 12/391 (3.1%)
  - Manual: 28/371 (7.5%)

- Reported $P=0.006$
  - Unclear whether adjustment for clustering
Review: Mechanical chest compressions versus manual chest compressions for cardiac arrest
Comparison: 02 Mechnical CPR versus Manual CPR
Outcome: 02 Return of Spontaneous Circulation

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>Mechanical CPR n/N</th>
<th>Manual CPR n/N</th>
<th>RR (random) 95% CI</th>
<th>Weight %</th>
<th>RR (random) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halperin 1993</td>
<td>8/17</td>
<td>3/17</td>
<td>0.87 (0.85, 0.87)</td>
<td>87.80</td>
<td>2.67 (0.85, 8.37)</td>
</tr>
<tr>
<td>Dickinson 1998</td>
<td>1/7</td>
<td>0/10</td>
<td>0.12 (0.19, 8.71)</td>
<td>12.20</td>
<td>4.13 (0.19, 88.71)</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>24</td>
<td>27</td>
<td></td>
<td>100.00</td>
<td>2.81 (0.96, 8.22)</td>
</tr>
</tbody>
</table>

Total events: 9 (Mechanical CPR), 3 (Manual CPR)
Test for heterogeneity: Chi² = 0.07, df = 1 (P = 0.79), I² = 0%
Test for overall effect: Z = 1.89 (P = 0.06)
Survival to Hospital Admission

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>Mechanical CPR n/N</th>
<th>Manual CPR n/N</th>
<th>RR (random) 95% CI</th>
<th>Weight %</th>
<th>RR (random) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dickinson 1998</td>
<td>1/7</td>
<td>0/10</td>
<td>26.59</td>
<td>4.13 [0.19, 88.71]</td>
<td></td>
</tr>
<tr>
<td>Hallstrom 2006 1</td>
<td>102/394</td>
<td>229/373</td>
<td>73.41</td>
<td>0.42 [0.35, 0.51]</td>
<td></td>
</tr>
</tbody>
</table>
Survival at 4 Hours post-arrest

• One study reported
• Hallstrom 2006
  – Mechanical 104/394 (26.4%)
  – Manual 92/373 (24.7%)
  – Reported $p=0.62$
Survival to 24 hours post arrest

Review: Mechanical chest compressions versus manual chest compressions for cardiac arrest
Comparison: 02 Mechanical CPR versus Manual CPR
Outcome: 03 Survival at 24 hours after cardiac arrest

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>Mechanical CPR n/N</th>
<th>Manual CPR n/N</th>
<th>RR (random) 95% CI</th>
<th>Weight %</th>
<th>RR (random) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taylor 1978</td>
<td>4/24</td>
<td>4/26</td>
<td>74.33 [0.30, 3.86]</td>
<td>1.08</td>
<td>1.08 [0.30, 3.86]</td>
</tr>
<tr>
<td>Halperin 1993</td>
<td>3/17</td>
<td>1/17</td>
<td>25.67 [0.35, 26.04]</td>
<td>3.00</td>
<td>3.00 [0.35, 26.04]</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>41</td>
<td>43</td>
<td>100.00</td>
<td>1.41</td>
<td>1.41 [0.47, 4.21]</td>
</tr>
</tbody>
</table>

Total events: 7 (Mechanical CPR), 5 (Manual CPR)
Test for heterogeneity: Ch² = 0.64, df = 1 (P = 0.42), I² = 0%
Test for overall effect: Z = 0.61 (P = 0.54)
Survival to hospital discharge

- One study reported
- Hallstrom 2006
  - Mechanical: 23/394 (5.8%)
  - Manual: 37/373 (9.9%)
  - Reported p=0.06 (adjusted)
  - OR 0.57 95% CI (0.33-0.99)
    - Adjusted for clustering and covariates
Conclusion

• There is insufficient evidence to determine the effectiveness of mechanical chest compressions in adults with cardiac arrest
Implications for practice

• One trial (Hallstrom 2006) stopped early over concerns for safety
  – Reduced neurologically intact survival to hospital discharge (NS), and survival to a number of intermediate time points
  – Need to interpret this finding in context of other RCTs, non RCTs, methodological inconsistencies

• Widespread use of device cannot be recommended based on available data
Why Did This Result Occur?

- Unclear
- Possibilities
  - Training
  - System variations
  - Timing of compression pause to apply AutoPulse device
  - Hawthorne effect in manual CPR arm
  - Reperfusion injury
Implications for future research

• More data from randomized controlled trials are needed
1st 3 Minutes of CPR
Focus on Quality of CPR
Real Time Feedback

No CPR   Poor CPR   Great CPR
Endpoints

• Primary endpoint
  – Survival to hospital discharge

• Secondary endpoints
  – Return of spontaneous circulation
  – Survival to four hours
  – Neurological outcome
Protocol
Endpoints

• Primary endpoint
  – Survival to 4 hours post admission to hospital

• Secondary endpoints
  – ROSC on arrival
  – Survival to DC
  – Neurological outcome
Keys to Best Trial Protocol

• Data collection – paramedic data capture
• Statistical analysis adjusted for Utstein criteria
• Record/report patient physical measurements
  – Implications for device effectiveness, safety
• Consistent protocols and training across all providers
• Apply device as early as possible
• Measure, report and adjust analysis for CPR process/quality in both arms
  – Special attention to “no flow time”, and delay to shock
• Report/adjust for post-resuscitation care
  – Therapeutic hypothermia
  – Other ICU interventions
• Blind outcome assessors for neurologic outcome
• Power to find the minimal significant benefit
Lessons Learned from ROC
FUCK IT
I'm going home.