Salvaging the prehospital collapsed patients: Novel resuscitative measures and cerebral protection

A/Prof Marcus Ong
Senior Consultant, Clinician Scientist & Director of Research
Department of Emergency Medicine
Singapore General Hospital
Associate Professor
Duke-NUS Graduate Medical School
Office of Clinical Sciences
Chain of Survival

- Early Access - call 995
- Early CPR - be current
- Early Defibrillation - AED
- Early Advanced Care
Contents

- Quality of CPR
- Mechanical CPR devices
- Advanced Defibrillation
- Hypothermia
- Cardiac Arrest Prediction
Quality of CPR

- Quality of CPR is an important, and often overlooked factor affecting survival in Cardiac Arrest
- Factors affecting the quality of CPR: individual factors, training, awareness, technique and rescuer fatigue.
- Quality components of CPR include the rate, ratio, depth as well as ventilation-compression ratio
Quality of Cardiopulmonary Resuscitation During In-Hospital Cardiac Arrest

Benjamin S. Abella, MD, MPhil
Jason P. Alvarado, BA
Helge Myklebust, BEng
Dana P. Edelson, MD
Anne Barry, RN, MBA
Nicholas O’Hearn, RN, MSN
Terry E. Vanden Hoek, MD
Lance B. Becker, MD

Survival from cardiac arrest remains low despite the introduction of cardiopulmonary resuscitation (CPR) more than 30 years ago. The delivery of CPR, with correctly performed chest compressions and ventilations, exerts a significant survival benefit in both animal and human studies. Conversely, interruptions in CPR or failure to provide compressions during cardiac arrest (“no-flow time”) have been noted to have a negative impact on survival in animal studies. Adherence to CPR published guidelines clearly define how CPR is to be performed, but the parameters of CPR in actual practice are not routinely measured, nor is the quality known.

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.

Objectives To measure multiple parameters of in-hospital CPR quality and to determine compliance with published American Heart Association and international guidelines.

Design and Setting A prospective observational study of 67 patients who experienced in-hospital cardiac arrest at the University of Chicago Hospitals, Chicago, Ill, between December 11, 2002, and April 5, 2004. Using a monitor/defibrillator with novel additional sensing capabilities, the parameters of CPR quality including chest compression rate, compression depth, ventilation rate, and the fraction of arrest time without chest compressions (no-flow fraction) were recorded.

Main Outcome Measure Adherence to American Heart Association and international CPR guidelines.

Results Analysis of the first 5 minutes of each resuscitation by 30-second 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. Ventilation rates were high, with 60.9% of segments containing a rate of more than 20/min. Additionally, the mean (SD) no-flow fraction was 0.24 (0.18). 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.

See also pp 299 and 363 and Patient Page.
Effect of CPR Interruptions

Time

Ao pressure

= chest compression

Berg et al, 2001
Minimizing Interruptions to CPR

Berg et al, 2001
Small, pocket-sized, stand-alone devices: provide rescuers with real-time CPR feedback

CPR Feedback device (ZOLL)
Pocket QCPR feedback device for use with manual CPR (CPREZY)

Placement of the device should be on the sternum
LED pressure sensor – to indicate the target pressure required for patients of different weight and size

On/Off button

Yellow LED which flashes in time with 100bpm tone
AEDs with CPR Feedback

Defibrillator pads incorporating an accelerometer for QCPR feedback (Zoll E series defibrillation pads)
Defibrillator screen display incorporating QCPR feedback indicators (Zoll E series)
Phillips Heartstart MRX QCPR device
Improving the Quality of Cardio-Pulmonary Resuscitation and First Responder Defibrillation Using an Automated Defibrillator for Cardiac Arrests Occurring in National Kidney Foundation Dialysis Centres
Mechanical CPR
Mechanical CPR

- The problem with standard CPR (STD-CPR): provides only 1/3 of normal blood supply to the brain and 10-20% to the heart

- Problem of rescuer fatigue, CPR not consistent, and need to stop CPR during rescuer changes and patient transfers
Thumper Model 1007 Mechanical CPR System
Lund University Cardiopulmonary Assist System (LUCAS)
Use of an Automated, Load-Distributing Band Chest Compression Device for Out-of-Hospital Cardiac Arrest Resuscitation

JAMA 2006 June 295(22): 2629-2637
Ong MEH, Ornato JP, Edwards DP, Best AM,
Survival to Discharge (%) by Phases

STD-CPR (n=486)  2.9
LDB-CPR (n=278)  9.7

OR 3.63, 95% CI [1.90, 7.23]
<table>
<thead>
<tr>
<th>Study Component</th>
<th>Hallstrom et al, 2006¹²</th>
<th>Ong et al, 2006¹²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study design</td>
<td>Prospective, cluster randomized clinical trial</td>
<td>Retrospective, pre-post, observational study</td>
</tr>
<tr>
<td>Setting</td>
<td>EMS systems in 5 communities</td>
<td>Single EMS system</td>
</tr>
<tr>
<td>Primary population considered</td>
<td>Out-of-hospital cardiac arrest of presumed cardiac origin</td>
<td>Out-of-hospital cardiac arrest of presumed cardiac origin</td>
</tr>
<tr>
<td>Interventions</td>
<td>LDB-CPR vs manual CPR; “Quick-lock” rhythm check, then CPR with device applied when ready or manual CPR with randomization at first-shock evaluation</td>
<td>LDB-CPR vs manual CPR; Device applied “as early as possible” and CPR given before shock unless cardiac arrest witnessed</td>
</tr>
<tr>
<td>EMS response time (fire response or first vehicle)*</td>
<td>5.6 min</td>
<td>4.6 min</td>
</tr>
<tr>
<td>Manual CPR, 5.7 min</td>
<td>Manual CPR, 4.6 min</td>
<td></td>
</tr>
<tr>
<td>Mean time to LDB-CPR*</td>
<td>11.0 min</td>
<td>Not measured</td>
</tr>
<tr>
<td>Patients in VF/VT*</td>
<td>LDB-CPR, 31%</td>
<td>LDB-CPR, 24%</td>
</tr>
<tr>
<td>Manual CPR, 32%</td>
<td>Manual CPR, 21%</td>
<td></td>
</tr>
<tr>
<td>Time to first shock if VF/VT*</td>
<td>LDB-CPR, 11.8 min</td>
<td>Not measured</td>
</tr>
<tr>
<td>Manual CPR, 9.7 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary outcome*</td>
<td>Survival to 4 h: LDB-CPR, 26%; Manual CPR, 25%</td>
<td>RCGS: LDB-CPR, 36%; Manual CPR, 20%</td>
</tr>
<tr>
<td>Selected secondary outcomes*</td>
<td>Survival to hospital discharge: LDB-CPR, 6%; Manual CPR, 10%</td>
<td>Survival to hospital discharge: LDB-CPR, 10%; Manual CPR, 9%; Good neurological outcome (CPC score of 1 or 2): LDB-CPR, 6%; Manual CPR, 2%</td>
</tr>
<tr>
<td></td>
<td>Good neurological outcome (CPC score of 1 or 2): LDB-CPR, 3%; Manual CPR, 8%</td>
<td></td>
</tr>
<tr>
<td>Primary analysis</td>
<td>Intention-to-treat, multivariable logistic regression modeling with clustering</td>
<td>Intention-to-treat, multivariable logistic regression modeling</td>
</tr>
<tr>
<td>Potential confounders</td>
<td>Unequal time to first shock for VF group, heterogeneity of treatment sites, interaction of treatment effect and response time, unknown quality of CPR, and potential for enrollment bias</td>
<td>Secular trends in outcomes, unequal advanced life support response times, unequal fraction witnessed arrests, unknown quality of manual CPR, and introduction of postresuscitation hypothermia</td>
</tr>
</tbody>
</table>
Device should not be seen as the ‘miracle’ solution to cardiac arrest

Multiple factors will affect cardiac arrest outcomes

The AutoPulse™ should be seen as a possible new component of an overall resuscitation strategy

Challenge is to incorporate this in current treatment protocols seamlessly
Interruptions to CPR during device deployment
No Flow Time for 1st 5 mins of resuscitation over LDB phase of the study
Use of an Automated, Load-Distributing Band Chest Compression Device for Cardiac Arrest Resuscitation: A Multi-Centre Clinical Trial

A/Prof Marcus Ong
Consultant, Senior Medical Scientist & Director of Research
Department of Emergency Medicine
Singapore General Hospital
## Comparison of clinical outcomes in the Pre-AutoPulse vs. AutoPulse phases

<table>
<thead>
<tr>
<th></th>
<th>Pre-AutoPulse N= 459</th>
<th>AutoPulse N= 552</th>
<th>Crude OR (95% CI)</th>
<th>Adjusted† OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%) return of spontaneous circulation</td>
<td>103 (22.44)</td>
<td>195 (35.33)</td>
<td>1.89 (1.43, 2.50)</td>
<td>1.07 (0.63, 1.83)</td>
</tr>
<tr>
<td>n (%) survival to hospital admission</td>
<td>65 (14.16)</td>
<td>109 (19.75)</td>
<td>1.49 (1.07, 2.09)</td>
<td>2.50 (1.05, 6.00)</td>
</tr>
<tr>
<td>n (%) survival to hospital discharge</td>
<td>6 (1.31)</td>
<td>18 (3.26)</td>
<td>2.55 (1.00, 6.47)</td>
<td>3.99 (1.06, 15.02)</td>
</tr>
</tbody>
</table>

† The model was adjusted for hospital, arrest location, bystander witnessed, ems witnessed, initial rhythm, prehospital defibrillation and autopulse applied.
Survival to discharge for Pre and Post Phases stratified by periods
CPC/OPC of survivors in the Pre-AutoPulse vs. AutoPulse phases

<table>
<thead>
<tr>
<th>Performance categories+</th>
<th>Pre-AutoPulse (n= 459)</th>
<th>AutoPulse (n= 552)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPC 1, n (%)</td>
<td>1 (&lt;0.01)</td>
<td>12 (0.02)</td>
<td></td>
</tr>
<tr>
<td>CPC 2, n (%)</td>
<td>1 (&lt;0.01)</td>
<td>1 (&lt;0.01)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CPC 3, n (%)</td>
<td>4 (0.01)</td>
<td>1 (&lt;0.01)</td>
<td></td>
</tr>
<tr>
<td>CPC 4, n (%)</td>
<td>0 (0.00)</td>
<td>2 (&lt;0.01)</td>
<td></td>
</tr>
<tr>
<td>OPC 1, n (%)</td>
<td>1 (&lt;0.01)</td>
<td>10 (0.02)</td>
<td></td>
</tr>
<tr>
<td>OPC 2, n (%)</td>
<td>1 (&lt;0.01)</td>
<td>2 (&lt;0.01)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>OPC 3, n (%)</td>
<td>4 (0.01)</td>
<td>2 (&lt;0.01)</td>
<td></td>
</tr>
<tr>
<td>OPC 4, n (%)</td>
<td>0 (0.00)</td>
<td>2 (&lt;0.01)</td>
<td></td>
</tr>
</tbody>
</table>

CPC= Cerebral Performance Category; OPC= Overall Performance Category
Resuscitation Protocol - AutoPulse™ Incorporated
Pit Crew Philosophy to Integration of AutoPulse™ into Resuscitation Protocol

- Efficient method of utilizing all available resources
- Each crew member has a defined role and position relative to patient.
- AutoPulse™ readied for application while manual compressions are being performed.
Advanced Defibrillation

iphone
AED
location
app
See-thru CPR

- Signal processing to filter ‘noise’ from the ECG signal
- No need to stop CPR to analyse rhythm and deliver shock
Intelligent Shock Prediction

- Advisory on timing of shocks to maximise success
- Based on VF waveform analysis
- Timing synchronized with chest compressions
Synchronized Defibrillation During Compression Upstroke.
A Randomised Controlled Trial Comparing Shock Success During Ongoing Mechanical Cardiopulmonary Resuscitation In The Emergency Department With And Without Synchronized Defibrillation During Compression Upstroke.
An advisory statement by the Advanced Life Support Task Force of the International Liaison Committee on Resuscitation (ILCOR – includes AHA)
(Published in Resuscitation, June 2003 and Circulation, July 2003)

- Unconscious adult patients with spontaneous circulation after out-of-hospital cardiac arrest should be cooled to 32-34° C for 12-24 hours when the initial rhythm was ventricular fibrillation (VF).

- Such cooling may also be beneficial for other rhythms or in-hospital cardiac arrest.

**Level 1 Evidence**
Three randomized clinical studies have been reported showing improved neurological outcome and reduced mortality in post-resuscitation patients treated with hypothermia compared to controls


## HACA Results

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Hypothermia</th>
<th>Normothermia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Favorable</td>
<td>75/136 (55%)</td>
<td>54/137 (39%)</td>
</tr>
<tr>
<td>Death</td>
<td>56/137 (41%)</td>
<td>76/138 (55%)</td>
</tr>
</tbody>
</table>

HACA Study Group NEJM 2002;346:549-56
“A Prospective Clinical Study Comparing Controlled Therapeutic Hypothermia Post-Cardiac Arrest Using External and Internal Cooling to Standard Intensive Care Unit Therapy”

Marcus Ong MD, MPH, FRCS A&E (Edin), FAMS
Dept of Emergency Medicine
Singapore General Hospital
Alsius Patient Temperature Management

Core Temperature Control and Central Venous Access

ALSIOUS
Intravascular Temperature Management (IVTM™)
How Does It Work???

Blood cools down after flowing over balloons

\[ T_1 = 37\, ^\circ C \]

\[ T_2 = 36.5\, ^\circ C \]

Cool Saline flows through catheter and balloons

Heat exchange with the blood

Blood flows
Temperature Chart from Internal Cooling Device
Cooling Chart (External Device)

External Cooling Phase

Temperature (Degrees Celsius)

Time

Patient’s Temp

Target Temp
Development of Intelligent Cardiac Arrest Prediction using Real-Time Measurement of Heart Rate Variability, Clinical Data and Vital Signs as a Bedside Triage Device

PI: Dr Marcus Ong Eng Hock¹
Co-PI: A/Prof Lin ZhiPing²
Collaborators: A/Prof Ser Wee², A/Prof Huang Guang-Bin², Papia Sultana³
Key Team Member: Liu Nan¹, Koh ZhiXiong¹

¹ Department of Emergency Medicine, Singapore General Hospital
² School of Electrical and Electronic Engineering, Nanyang Technological University
³ Department of Clinical Research, Singapore General Hospital
Real-time Cardiac Arrest Prediction System

ECG Sensors

NIBP & SpO2
## Performance of Vital Signs and HRV for cardiac arrest prediction within 72 hrs

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group</th>
<th>AUC (95%CI)</th>
<th>Sensitivity (95%CI)</th>
<th>Specificity (95%)</th>
<th>PPV (95%)</th>
<th>NPV (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vital Signs</strong></td>
<td>Cardiovascular</td>
<td>0.845 (0.703, 0.986)</td>
<td>41.67 (16.50, 71.40)</td>
<td>99.03 (97.37, 99.69)</td>
<td>55.56 (22.65, 84.66)</td>
<td>98.32 (96.41, 99.26)</td>
</tr>
<tr>
<td></td>
<td>Non-cardiovascular</td>
<td>0.748 (0.657, 0.838)</td>
<td>30.00 (17.09, 46.71)</td>
<td>94.42 (92.09, 96.12)</td>
<td>27.91 (15.83, 43.90)</td>
<td>94.94 (92.67, 96.55)</td>
</tr>
<tr>
<td><strong>Demographics</strong></td>
<td>Cardiovascular</td>
<td>0.955 (0.902, 1.000)</td>
<td>66.67 (35.44, 88.73)</td>
<td>98.06 (96.07, 99.10)</td>
<td>50.00 (25.51, 74.49)</td>
<td>99.02 (97.34, 99.69)</td>
</tr>
<tr>
<td>HRV parameters</td>
<td>Cardiovascular</td>
<td>0.832 (0.772, 0.893)</td>
<td>52.50 (36.34, 68.18)</td>
<td>90.65 (87.84, 92.88)</td>
<td>28.77 (19.07, 40.72)</td>
<td>96.37 (94.28, 97.74)</td>
</tr>
</tbody>
</table>

Demographic parameters: age  
Vital Signs parameter: temperature, pulse rate, respiratory rate, sbp, dbp, spo2 and pain score  
HRV parameters: aRR, STD, avHR, sdHR, RMSS, nn50(count), pnn50(%), RR triangular index, TINN (ms), LS-VLF power (ms2), LS-LF power (ms2), LS-HF power (ms), LS-total power (ms2), LS-LF power (nu), LS-HF power (nu) and LS-LF/HF ratio
## Results

**Multivariate logistic regression models**

### Performance of Vital Signs and HRV for death prediction

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Variables</th>
<th>AUC (95%CI)</th>
<th>Sensitivity (95%CI)</th>
<th>Specificity (95%)</th>
<th>PPV (95%)</th>
<th>NPV (95%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>Vital signs</td>
<td>0.845 (0.745, 0.944)</td>
<td>45.45 (18.14, 75.44)</td>
<td>99.52 (98.07, 99.92)</td>
<td>71.43 (30.26, 94.89)</td>
<td>98.56 (96.74, 99.41)</td>
</tr>
<tr>
<td>Death</td>
<td>Demographics, HRV parameters, Vital signs</td>
<td>0.966 (0.939, 0.994)</td>
<td>63.64 (31.61, 87.63)</td>
<td>97.83 (95.77, 98.94)</td>
<td>43.75 (20.75, 69.45)</td>
<td>99.02 (97.34, 99.68)</td>
</tr>
</tbody>
</table>

**Demographic parameters**: age and gender.

**Vital Signs parameter**: temperature, pulse rate, respiratory rate, SBP, DBP, SpO₂ and pain score

**HRV parameters**: aRR, STD, avHR, sdHR, RMSS, nn50(count), pnn50(%), RR triangular index, TINN (ms), LS-VLF power (ms²), LS-LF power (ms²), LS-HF power (ms), LS-total power (ms²), LS-LF power (nu), LS-HF power (nu) and LS-LF/HF ratio
Incorporation of HRV Analysis

Cardiac arrest prediction score: 1-100

RR interval sequence
Wearable, Ambulatory, Automatic Monitoring and Risk Prediction System

- Database
- Intelligent information system
- Risk prediction system

Innovative medical device
- Chest band: ECG measurement
- Wrist-worn gadget
  - Reflectance pulse oximetry
  - Blood pressure derivation
  - Motion artifact reduction
- Low-power consumption
- SD card storage
- Risk prediction analysis

Content server (Hospital)
- WAP device (Patient’s)
  - User interface
  - Off-line view the recorded signal
  - Upload the saved data to the server

WAP device (Doctor’s)
  - User interface
  - Remote access and download the data on the content server
  - Display of patient’s data, monitored vital signs and risk analysis results

- Home-based Patients
- Hospital-based patients
- Doctors
- Family
- Clinicians
- Physicians