Moving Codes Upstairs - How the ratio of PICU arrests is increasing and why it’s a good thing

Robert A. Berg, MD, FCCM, FAHA, FAAP
Division Chief, Critical Care Medicine
The Children’s Hospital of Philadelphia

Russell Raphaley Endowed Chair, Department of Anesthesiology and Critical Care Medicine

Professor of Anesthesiology and Critical Care Medicine and Pediatrics, Perelman School of Medicine at the University of Pennsylvania
Moving Codes Upstairs
The ratio of PICU CPR is increasing and it's a good thing

Bob Berg
CHOP
No Financial Conflicts of Interest

• **Employment:** University of Pennsylvania

• **AHA Volunteer**
  – Past Chair, GWTG-R committee
  – Past Chair, BLS Committee
  – Past Chair, PALS Committee

• **Grants:** NICHD, NHLBI, AHA, Medtronic, Laerdal

• **Intellectual Conflicts of Interest**
  – >25 yrs of Cardiac Arrest & CPR Research
Introduction

• History
• Epidemiology
  – Ward Pediatric CPR is rare
  – PICU CPR not so rare
• CPR Quality
  – PUSH HARD and FAST
  – Allow Full Chest Recoil
• Post-resuscitation Care
• HOT: Duration & Debriefing
“Closed-chest massage”
Kouwenhoven, JAMA 1960

- While studying defibrillation in small dogs
  - Ao pressure increased with paddles
  - Adequate circulation for 30 min
- 20 patients: asphyxia in OR
- 20/20 survived the cardiac arrest
- 14/20 long-term survivors
“Cardiac Arrest”
Jude, Kouwenhoven, Knickerbocker, JAMA 1961

Fig. 3.—Examples of arterial blood pressure developed with external cardiac massage. Age and size of chest did
Arterial Blood Pressure during CPR
Jude, JAMA 1961

BLOOD PRESSURE WITH EXTERNAL CARDIAC MASSAGE

AGE 8 POSTOP. CARDIAC SURGERY
In-hospital cardiac arrests
CHOP—1981-1982

- 18 children with asystole
- 2/18 (11%) survived to d/c
- 0/21 survived after >2 doses of epi

Nichols D, Kettrick R, Swedlow D…Ludwig S, Ped Emerg Care, 1986
In-hospital cardiac arrests

Children’s National (CNMC) 1984-1985

- 53 pulseless arrests
- 5/53 (9%) survived to D/C
- 0/31 survived after >2 doses of epi
- No survivors when CPR >10 min

Zaritsky A, Nadkarni V, et al. AEM 1987
PALS: Outcome of Respiratory vs Cardiopulmonary Arrest in Children

Survival Rate

- Respiratory Arrest: 100%
- Cardiopulmonary Arrest: 0%
Annual Incidence of Pediatric CPR in USA

In-hospital (KIDS database)

>6,000/year

Knudson...Rossano, CCM 2012
In-hospital Pediatric CPR
GWTG-R

N=880

ROSC: 60%

24-hr survival: 36%

Survive to d/c: 27%

Favorable Neuro: 22/81%

Nadkarni......Berg, JAMA 2006
Immediate Cause

Pediatric In-hospital Cardiac Arrest

<table>
<thead>
<tr>
<th>Cause</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory Insufficiency</td>
<td>57%</td>
</tr>
<tr>
<td>Hypotension</td>
<td>61%</td>
</tr>
</tbody>
</table>

Nadkarni.....Berg, JAMA 2006
95% of pediatric ICU+Ward CPR is in the ICU

~60% adults in ICU

In-hospital CPR training should focus on ICU CPR

Berg, CCM 2013
CPR at CHOP
21st Century

- 0-2 ward CPR events/year
  - Dx and Rx resp failure and shock
  - PEARs training
- ~30 PICU CPR events/year
  - Get patient to PICU
  - Advanced life support training
CPCCRN PICU CPR
2012-2013

• 1.4% of >10,000 PICU admission
• Survival to discharge: 45%
• Survival with favorable neuro: 40%/89%

Berg, CPCCRN investigators, unpublished
Pediatric Resuscitation

It’s worth the effort
Four Phases of Cardiac Arrest

- Pre-arrest
- “No flow”---untreated arrest
- “Low flow”---CPR
- Post-resuscitation
Pre-arrest

1) Prompt Dx and Rx of Respiratory Failure and Shock

The Focus of PALS course
- Medical Emergency Teams/RRTs
- Fewer deaths
- Fewer non-ICU “codes”
  - Sharek, JAMA 2007
  - Tibbals, PCCM 2009

2) Monitor critically ill children

Non-ICU ped cardiac arrest is a sentinel event (potentially avoidable medical error)
“No flow” phase

• Do something!!
  – Push Hard, Push Fast
  – Allow Full Chest Recoil
  – Minimize interruptions
  – Don’t overventilate

• In hospitals: monitor for cardiac arrest and treat promptly
“Low flow” phase

CPR

Chest compressions provide entire cardiac output

- Stroke volume: **PUSH HARD**
- Heart Rate: **PUSH FAST**
Adequacy of Pediatric CPR

- Cardiac Output ~10-25% of NSR
  - Pulmonary blood flow ~10-25%
  - “Normal” ventilation not necessary

- Myocardial and Cerebral Blood Flow
  - >50% of NSR
Coronary Perfusion Pressure
Critically Important for Successful
CPR

“Coronary Perfusion Pressure”
During CPR

AoD >30 mmHg; CPP >20 mmHg

Sanders, CCM 1984
Michael, Circ 1984
Kern, Resus 1988
Crile, Expt Med 1906
Coronary Perfusion Pressure during 15:2 CPR
(Ao diastolic - RA diastolic) Berg, Circulation 2001
Interruption of compressions
Worse hemodynamics

• Lower # of compressions/min
• Decrement in AoD
• Lower LV myocardial blood flow
• Can result in worse outcomes
• **Minimize interruptions!**

Effect of “Leaning” Flows during CPR

<table>
<thead>
<tr>
<th></th>
<th>No Lean</th>
<th>10 %</th>
<th>20 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBF</td>
<td>0.40 ± 0.34*</td>
<td>0.24 ± 0.22</td>
<td>0.19 ± 0.12</td>
</tr>
<tr>
<td>CI</td>
<td>1.78 ± 0.77*</td>
<td>1.21 ± 0.61</td>
<td>0.95 ± 0.32</td>
</tr>
</tbody>
</table>

*P<0.05, No Lean vs. 10% & 20%

Zuercher, CCM 2010
Time to Epinephrine following Pediatric In-Hospital Cardiac Arrest: GWTG-R

Andersen LW, Berg K, Saindon BZ, Massaro JM, Raymond TT, Berg RA, Nadkarni VM, Donnino MW (unpublished data)
“High quality CPR is the primary component influencing survival”

“Monitor CPR,” but what targets?
Measure CC Rate, Depth, Force, and Residual Leaning
CPR Quality at CHOP 2006-2008

Sutton, CHOP CPR investigators, Pediatrics 2009
“High quality CPR is the primary component influencing survival”

“Monitor CPR,” but what targets?
Vinay Nadkarni
Bobby Sutton
Mary Ann Diliberto
Dana Niles
Bob Berg
Bob Tamburro
& CPCCRN investigators
CPCCRN PICqCPR

“High Quality CPR”
(Rate≥100, CCF ≥0.80; DBP≥25 mmHg)

- 40% of CPR minutes (IQR: 0%, 70%)

- Survivors vs non-survivors
  60% vs 20% of CPR minutes

Poor Performance and Variable Care
Potential to Improve!

CPCCRN investigators, preliminary data
Is a life as important as a car race?
Focused Efforts to Improve Skills

Environment

Team

Individually

Just-in-Time Training

Performance

Debriefing

Performance Feedback
The Individual
“Rolling Refresher”

A mobile cart with manikin to provide 30-90 second *in situ* CPR practice with feedback to optimize CPR skills.
Refreshers Improve CPR

Retention Increased from 17 to 70%!

Sutton, Pediatrics 2011
The Team
INTEGRATED TEAM

• Simultaneous, choreographed approach
  • 1st rescuer: CCs
  • Next rescuers:
    • Rhythm detection & Shock (if necessary)
    • Bag-mask ventilation
Debriefing Improves CPR

RAPID = Resuscitation with Actual Performance Integrated Debriefing

- Ventilation Rate: Baseline 38 vs. RAPID 49
- Compression Rate: Baseline 65 vs. RAPID 82
- Compression Depth: Baseline 70 vs. RAPID 86

* Indicates statistically significant difference.

Edelson, Arch Intern Med 2008
Debriefing Improves ROSC

Adj OR: 1.83 CI\textsuperscript{95} 1.06-3.16, p=0.03

Edelson, Arch Intern Med 2008
How often do we perform CPR?

- 55 bed Pediatric Intensive Care Unit
- 3600 admissions per year
- ~30 CPR events per year
- 15 fellows → 2.0 arrest/yr
- 26 attendings → 1.1 arrests/yr
- 110 residents → 0.3 arrests/yr
- 250 RNs → 5 RNs/arrest → 0.6 arrests/yr
How Do Teams work Together?

Possible teams

715,000

How do teams work well together when they don’t work together consistently?
The Environment
Resuscitation Quality Improvement Debriefing

- Nurses, Respiratory Care, Residents, Fellows, Attendings, Pharmacy
- All ICU providers
  - not limited to code team
- Non-punitive environment

**Goal:** To improve CPR delivered in our ICU
Interdisciplinary Resuscitation Debriefings

- Monthly
- MDs, RNs, RTs, Surgeons
- Quality of Resuscitation
- Examples of excellence
- Clinical issues - System issues
- Team performance
- Patient Physiology focused

Real Life CPCCRN Example

What if I told you this went on for 2 minutes without CPR?

And was never shocked?
Debriefing: Before After Study

Wolfe, CCM, 2014

N=52

Pediatric Advanced Life Support Certification
Weekly Mock Code Program
Feedback Enabled Defibrillation
CPR Retraining of Front Line Personnel

N=42

Interdisciplinary Debriefings

Control – 18 months
Censor – 6m
Intervention – 18 months
Debriefing at CHOP
Debriefing at CHOP

†adj OR 2.5 (0.91-6.8) *adj OR 2.75 (1.01-7.5)

120 CPR events
60 pre-
60 post-
• Brain injury
• Myocardial dysfunction
• Ischemia-reperfusion injury
  • SIRS
• Persistent precipitating pathology
# Post-Cardiac Arrest Syndrome

<table>
<thead>
<tr>
<th>Condition</th>
<th>Odds of Death</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension ≤ 6 hrs</td>
<td>1.71</td>
<td>1.02-2.89</td>
</tr>
<tr>
<td>LV dysfunction ≤ 24 hrs</td>
<td>13.7</td>
<td>1.54, 122</td>
</tr>
<tr>
<td>Status Epilepticus EEG</td>
<td>5.1</td>
<td>1.4, 18</td>
</tr>
</tbody>
</table>

Topjian, CCM 2014  
Conlon, PCCM 2015  
Topjian, CCM 2013
Post-Cardiac Arrest Care

- Myocardial dysfunction is common
- Avoid hypotension
- Treat with vaso-active agents
- Monitor temperature
- Actively avoid hyperthermia
- Monitor EEG: Rx seizures
- Avoid hyperoxia
CPR duration in kids

GWTG-R

Adjusted probability of survival

CPR 1-15 min: 41%
CPR >35 min: 12%

Among survivors, favorable neuro

CPR 1-15 min: 70%
CPR >35 min: 60%

Matos, Watson, Nadkarni, Huang, Berg, Meaney, Carroll, Berens, Praestgaard, Weissfeld, Spinella, Circulation 2013
IHCA Survival Improving

GWTG-R: 1,031 children

Risk-adjusted Survival Rate Increased
14.3% in 2000 to 43.5% in 2009

Adj rate ratio/year 1.08; 95% CI [1.01,1.16]

Girotra, Spertus, Li, Berg, Nadkarni, Chan
Circ Cardiovasc Qual Outcomes 2013
CPCCRN PICU CPR
2012-2013

- 1.4% of >10,000 PICU admission
- Survival to discharge: 45%
- Survival with favorable neuro: 40%/89%

Berg, CPCCRN investigators, unpublished
Conclusions

- Pediatric CPR is common, yet rare
  - Get patient to PICU before CPR
- CPR: *JUST DO IT!!!*
  - Push Hard, Push Fast
  - Avoid interruptions
  - Don’t lean
- Practice individual skills
- Debrief as a TEAM
- Post-Cardiac Arrest Care
Future

• Ward CPR events are uncommon
  – ?A no-no?
• IHCA survival rates improving
  – Is there a limit?
• Duration of CPR: 12% survival >35 min
  – When should we stop?
• Debriefing is GOOD
It takes a village!!