# IX Congresso Nazionale SIMEU

# *Il bambino in arresto cardiaco*

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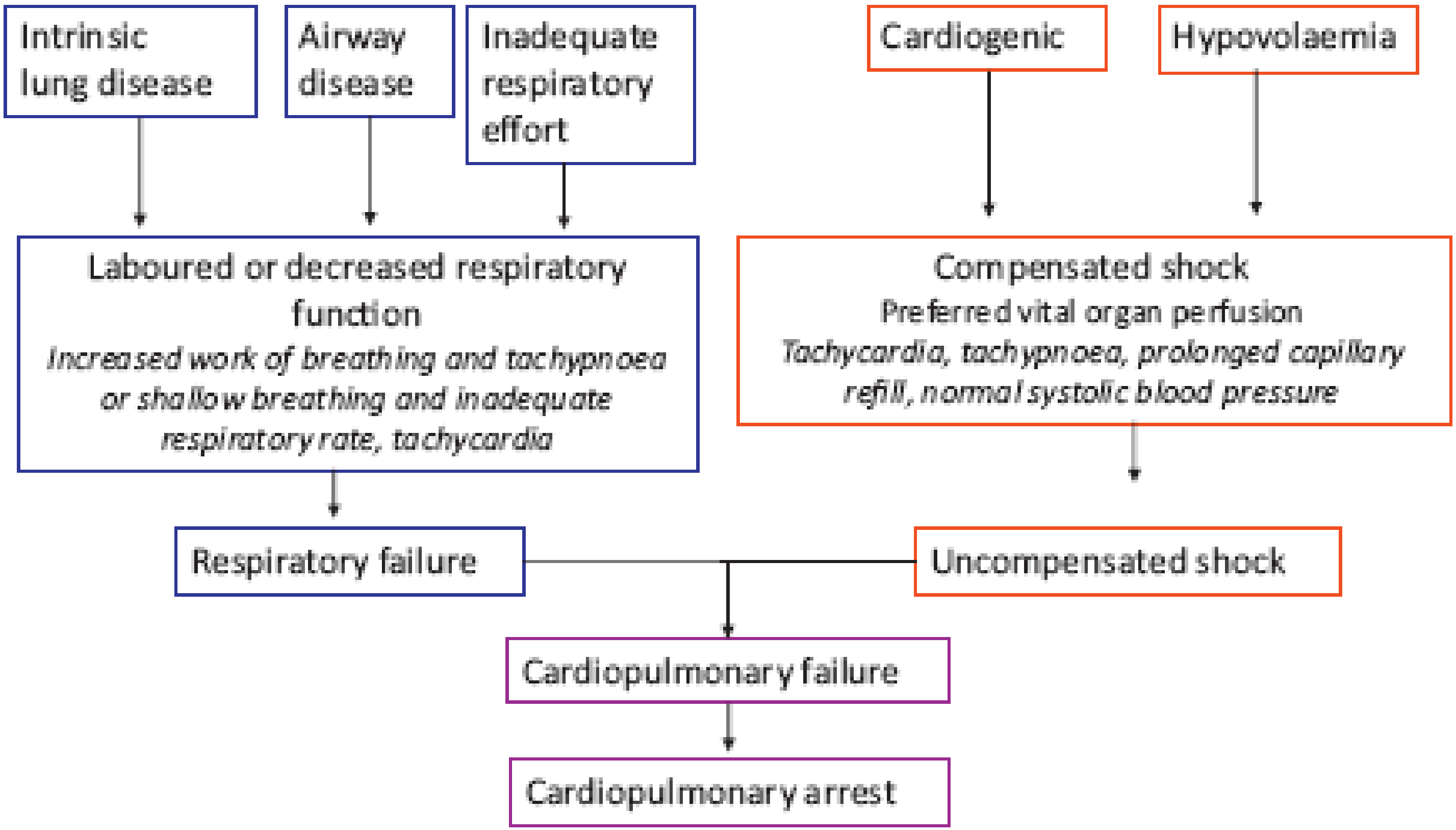
# Pathway of cardiopulmonary arrest




*J. Hammer / Paediatric Respiratory Reviews 14 (2013) 64–69*

# Pediatric Cardiac Arrests: epidemiology

## Out-of-Hospital Cardiac Arrest

~5000 children/yr in US

Atkins D, ROC investigators, Circulation 2009

## In-Hospital PICU Cardiac Arrests

>4000 children/yr in US

Slonim, Crit Care Med 1999. Randolph, J Peds 2004

**About 300,000 adult cardiac arrests in the US each year**

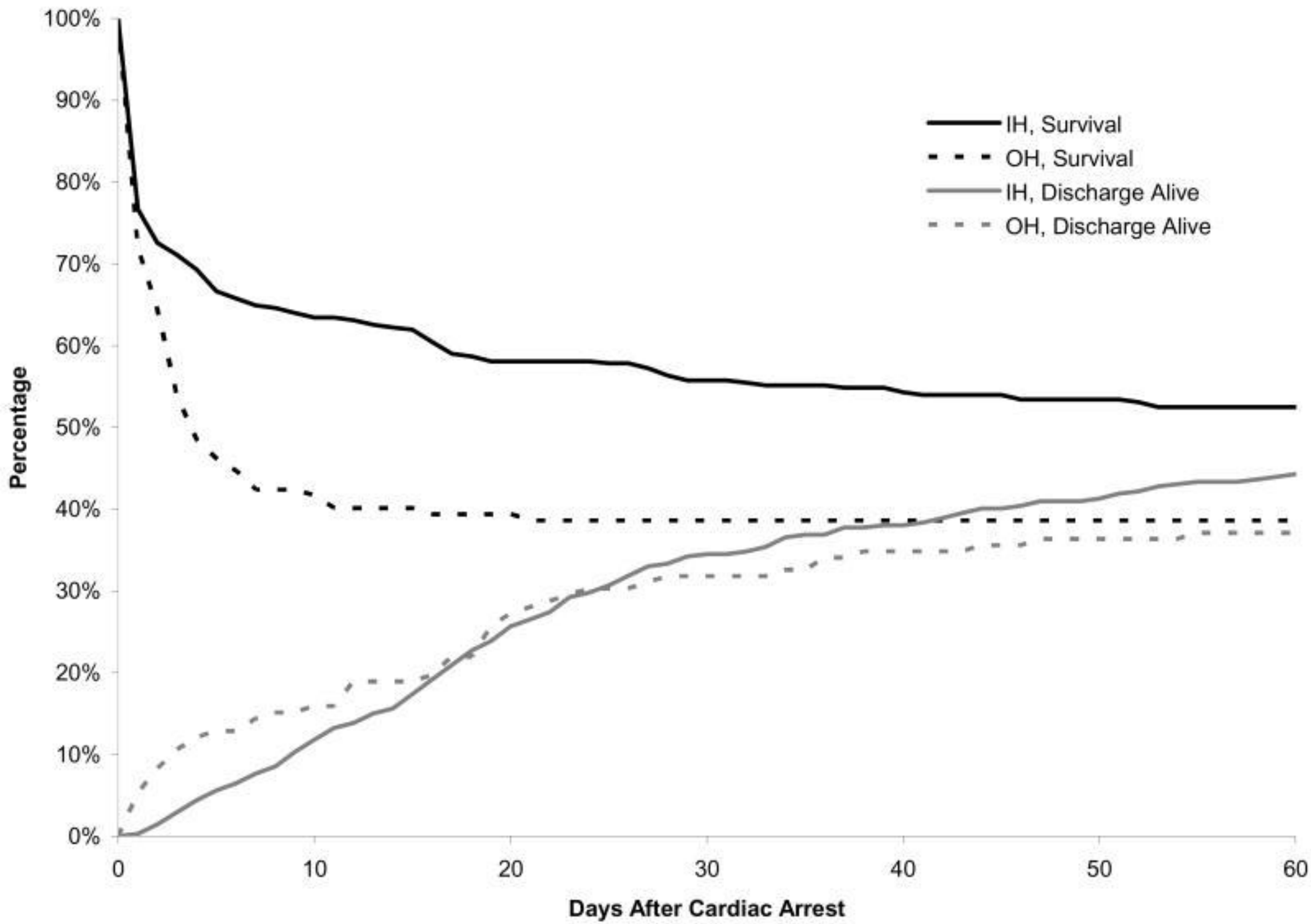
# Moler FW et al, IH vs OH Pediatric CA: a multicenter cohort study. PECARN Crit Care Med, 2009;37:2259

| | IH Overall (N=353) | OH Overall (N = 138) | P-Value[b] |
|---|---|---|---|
| | *n (percent)* | *n (percent)* | |
| Cardiac (not congenital heart disease) | 124 (36) | 20 (15) | < 0.01 |
| Arrhythmia | 42 (12) | 13 (9) | |
| Hypovolemic shock | 19 (5) | 2 (1) | |
| Septic shock | 28 (8) | 2 (1) | |
| Cardiomyopathy | 8 (2) | 1 (1) | |
| Other | 41 (12) | 4 (3) | |
| Congenital heart disease | 130 (37) | 6 (4) | < 0.01 |
| Arrhythmia | 69 (20) | 4 (3) | |
| Low cardiac output | 38 (11) | 1 (1) | |
| Hypoxemia | 15 (4) | 2 (1) | |
| During post-op course | 52 (15) | 1 (1) | |
| Tamponade | 4 (1) | 0 (0) | |
| Other | 9 (3) | 2 (2) | |
| Respiratory | 145 (42) | 98 (72) | < 0.01 |

# Moler FW et al, IH vs OH Pediatric CA: a multicenter cohort study. PECARN Crit Care Med, 2009;37:2259

| | IH Overall (N = 353) | OH Overall (N = 138) | P-Value[b] |
|---|---|---|---|
| | *n (percent)* | *n (percent)* | |
| Day of arrest (if unavailable, using CPR, ROC, or arrival at hospital) | | | 0.71 |
| Weekday (Mon 12:00 am–Fri 11:59 pm) | 255 (72) | 102 (74) | |
| Weekend (Sat 12:00 am–Sun 11:59 pm) | 98 (28) | 36 (26) | |
| Time of arrest (if unavailable, using CPR, ROC, or arrival at hospital) | | | 0.28 |
| Day (7:00 am–6:59 pm) | 190 (54) | 80 (60) | |
| Night (7:00 pm–6:59 am) | 160 (46) | 54 (40) | |
| Day of arrest (if unavailable, using CPR, ROC, or arrival at hospital) | | | 0.95 |
| Weekday (Mon 7:00 am–Fri 10:59 pm) | 244 (70) | 93 (69) | |
| Weekend (Fri 11:00 pm–Mon 6:59 am) | 106 (30) | 41 (31) | |
| Time of arrest (if unavailable, using CPR, ROC, or arrival at hospital) | | | 0.05 |
| Day (7:00 am–10:59 pm) | 252 (72) | 108 (81) | |
| Night (11:00 pm–6:59 am) | 98 (28) | 26 (19) | |
| First monitored rhythm | | | < 0.01 |
| Asystole | 55 (16) | 64 (46) | |
| Bradycardia | 173 (49) | 14 (10) | |
| Pulseless electrical activity | 31 (9) | 14 (10) | |
| Ventricular fibrillation/tachycardia | 35 (10) | 9 (7) | |
| Other/Unknown | 59 (17) | 37 (27) | |
| Asystole rhythm documented (any time) | 101 (29) | 71 (51) | < 0.01 |
| VF/VT rhythm documented (any time) | 67 (19) | 30 (22) | 0.49 |

# Moler FW et al, IH vs OH Pediatric CA: a multicenter cohort study. PECARN Crit Care Med, 2009;37:2259



# OH Pediatric Cardiac Arrest Incidence (n=621), ROC registry

| Age | Incidence/100.000 p/yr |
|---|---|
| infants | 72.71/100,000 |
| children | 3.73/100,000 |
| adolescents | 6.37/100,000 |
| adults | 95/100,000 |

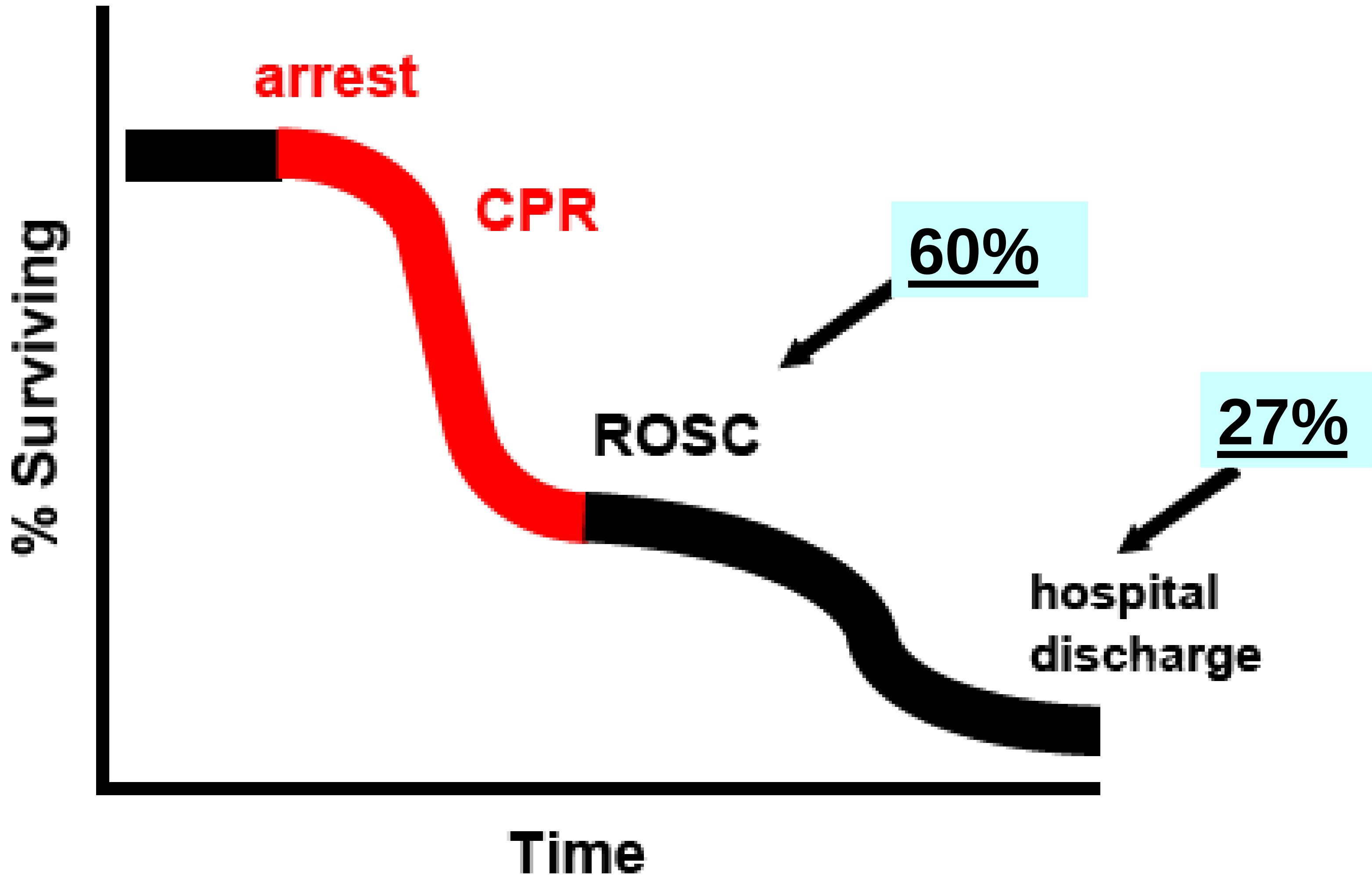
Atkins D et al. Epidemiology and Outcomes From Out-of-Hospital Cardiac Arrest in Children; the Resuscitation Outcomes Consortium Registry – Cardiac Arrest. Circulation 2009;119:1484

# OH Pediatric Cardiac Arrest Survival

| Age | Surv to d/c | Odds Ratio | 95% CI |
|---|---|---|---|
| infants | 3.3% | 0.71 | 0.37-1.39 |
| Children | 9.1% | 2.11 | 1.21 - 3.66 |
| adolescents | 8.9% | 2.04 | 1.24 - 3.38 |
| adults | 4.5% | 1.0 (Reference) | |

Atkins D et al. Epidemiology and Outcomes From Out-of-Hospital Cardiac Arrest in Children; the Resuscitation Outcomes Consortium Registry – Cardiac Arrest. Circulation 2009;119:1484

**Figure 1.** Schematic of survival from CA, with initial resuscitation (red) indicated. Survival percentages are illustrative of IHCA. From Nadkarni *et al.*[1]




**Nadkarni V. et al. JAMA 2006**

# Moler FW et al. Multicenter Cohort Study of Out-of-Hospital Pediatric Cardiac Arrest. Critic Care Med, 2011;39:141-149

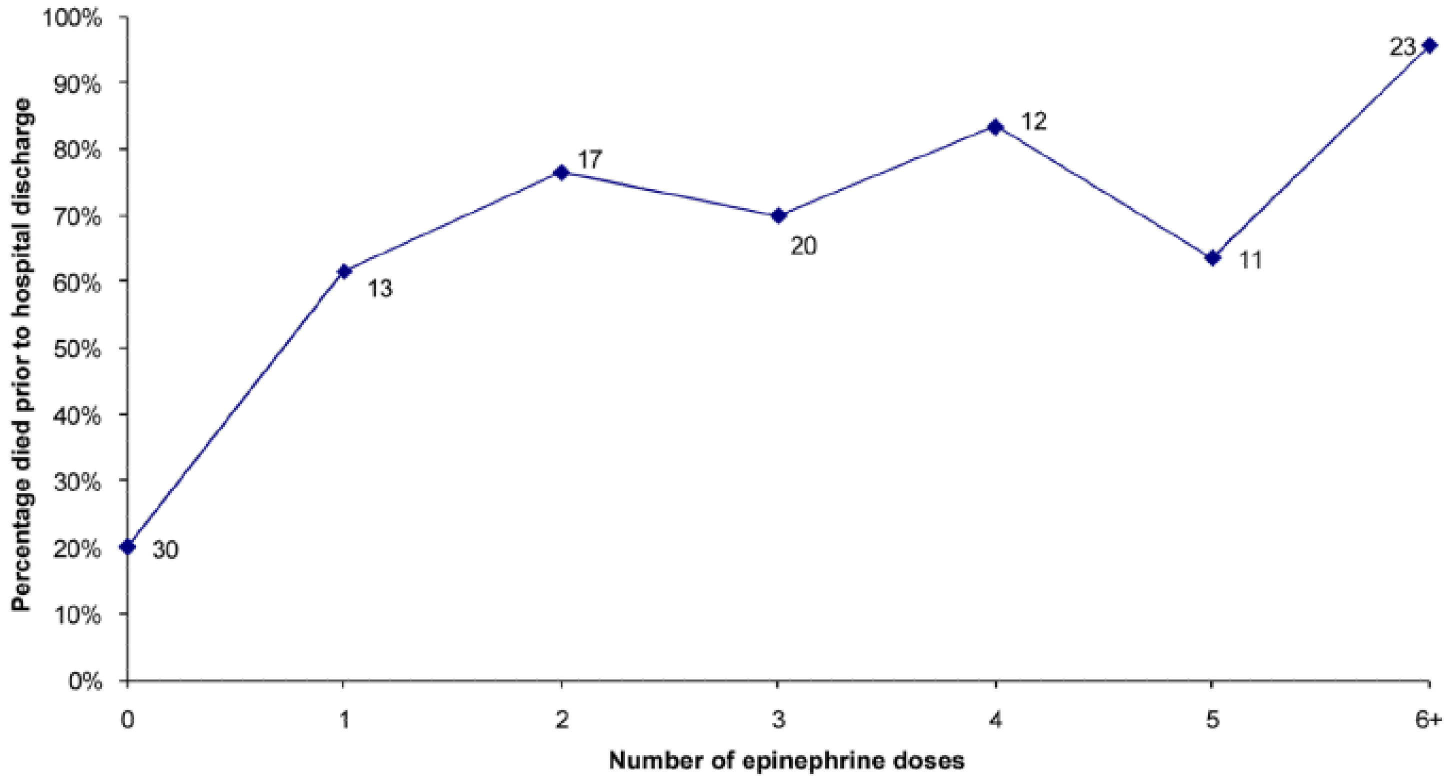



**Figure 1.**
Simple plot of mortality percent versus number of epinephrine doses received
Numbers on graph depict the number of cases who receiving the described epinephrine doses 12 missing cases from total of 138
Number of epinephrine doses was inversely associated with live hospital discharge ($p<0.01$).

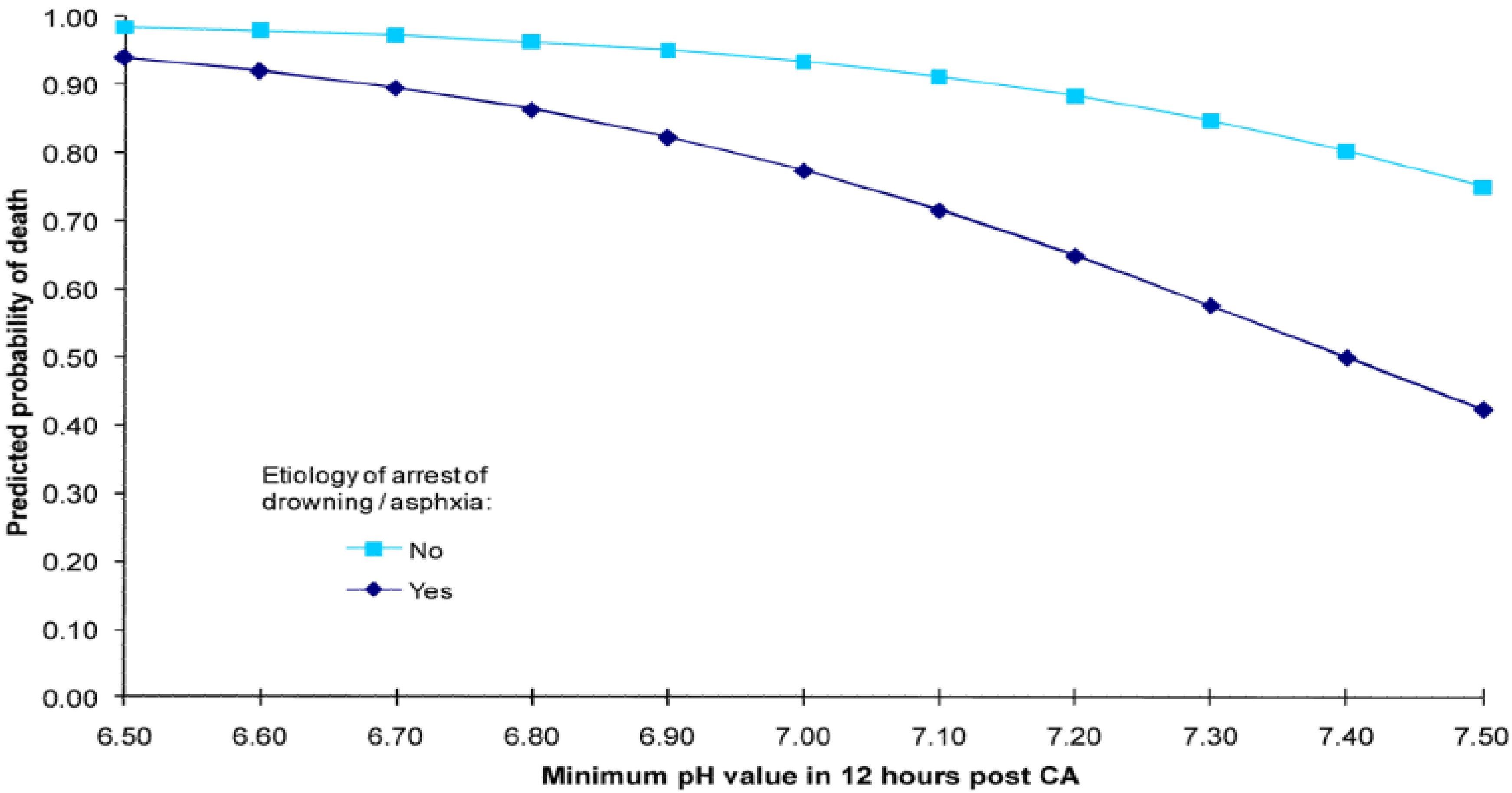



**Figure 2.**
Predicted probabilities of death for lowest pH values within 12 hours of ROC[a]
[a] Based on logistic regression Model 2 (including variables prior to, during, and up to 12 hours after cardiac arrest). The predicted probabilities are based on an "average" cardiac arrest patient with median age (2.9 years) and values for all other variables based on most frequently observed in population, ie, white male with asystole arrest rhythm and pupils not responsive at some point during 12 hours post-arrest.

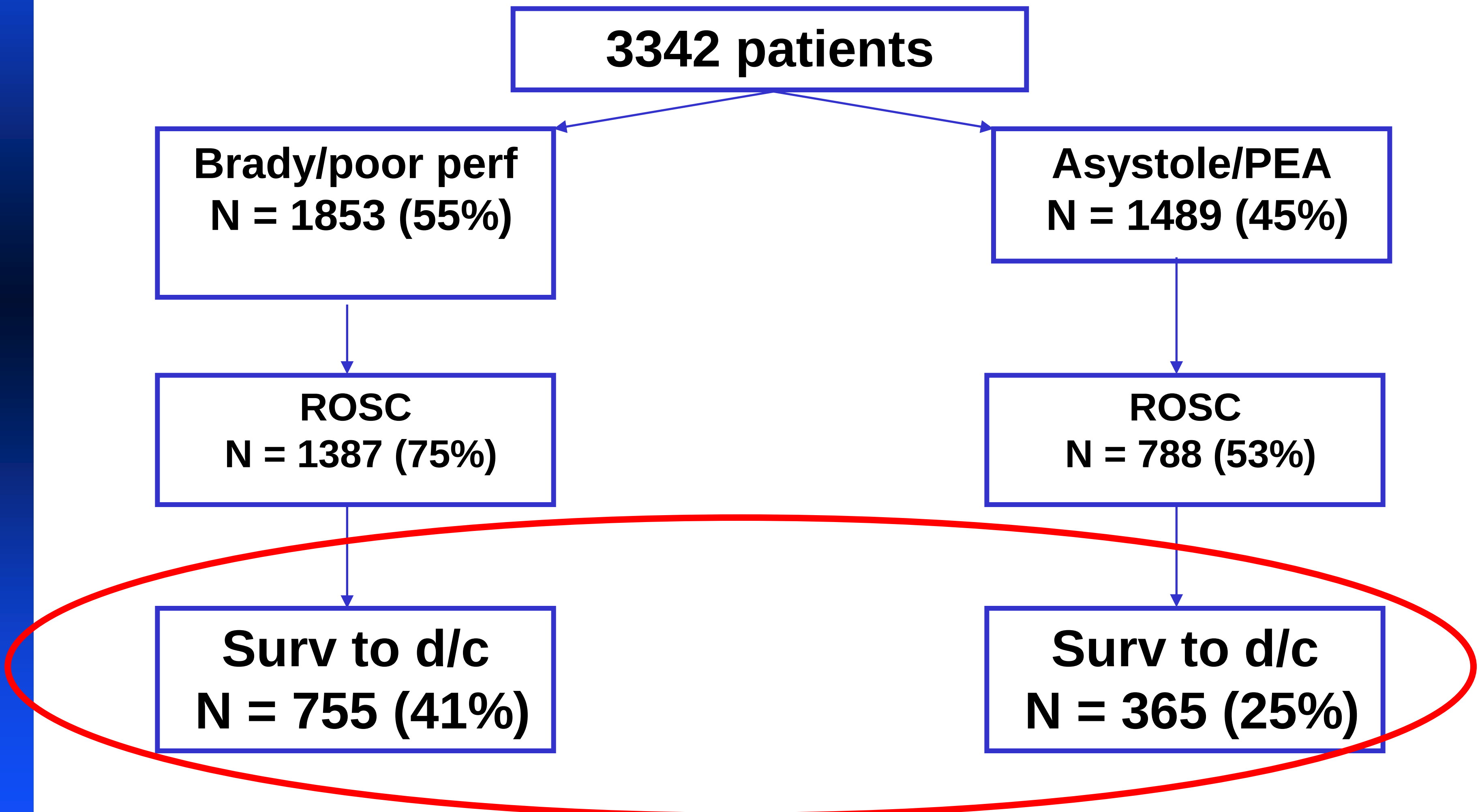
## Moler FW et al. Multicenter Cohort Study of Out-of-Hospital Pediatric Cardiac Arrest. Critic Care Med, 2011;39:141-149

**Event characteristics associated with survival:**

- weekend arrests,
- CPR not ongoing at hospital arrival,
- arrest rhythm not asystole,
- no atropine or $NaHCO_3$,
- fewer epinephrine doses,
- shorter duration of CPR,
- drowning or asphyxial arrest event.

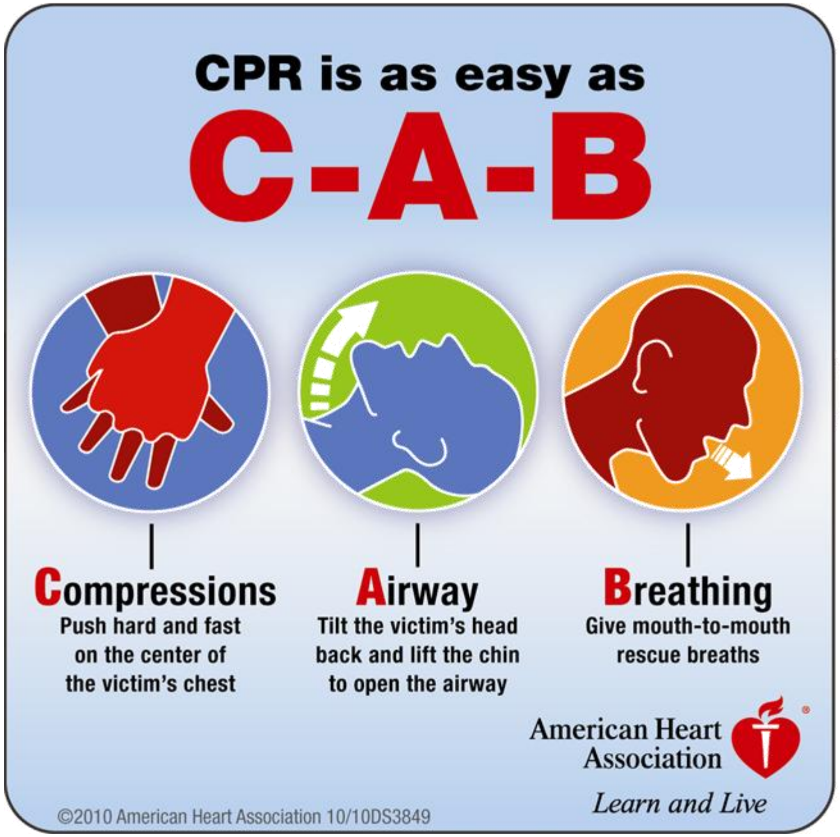
# CPR for bradycardia with poor perfusion vs PEA (CC>2 min) NRCR

Donoghue et al, NRCPR data, Pediatrics 2009;124:494



# CPR Sequence

- Change:
  - From A-B-C to C-A-B
  - Initiate chest compressions before ventilations
- Why?
  - Goal: Reduce delay to CPR, begin sequence with skill all can perform
  - Emphasize primary importance of compressions



# CPR Quality

1. *Push Hard:* ***at least*** 1/3 Chest Depth
   ~ 5 cm in children
   ~ 4 cm in infants

2. *Push Fast:* ***at least*** 100/minute

3. Minimize Interruptions ("no flow time")
   **CC during charging** of defibrillator
   **C**-AB

4. Allow full chest recoil

5. Don't Over-Ventilate

# Elimination of "Look, Listen, and Feel" for Breathing and 5 rescue breaths

**Change:**

- This action removed from the CPR sequence
- After delivery of 30 compressions, lone rescuer opens airway and delivers 2 breaths.

**Why?**

- Rescuer checks for response and "no breathing or no normal breathing" in adult before beginning CPR
- Starting CPR with compressions minimizes delay to action

# Lubrano R et al. Comparison of times of intervention during pediatric CPR maneuvers using ABC and CAB sequences: a randomized trial. Resuscitation. 2012;83:1473

- 340 volunteers for a 2-rescuer BLS
- Video-review manikin study
- Randomized Cross-over design
- Compare ABC vs. CAB
- Cardiac and Respiratory Scenario

| Scenario | Action | Sequence | | |
|---|---|---|---|---|
| | | ABC<br>Seconds from start | CAB<br>Seconds from start | $p <$ |
| Cardiac | Diagnosis of cardiac arrest | 41.67 ± 4.95 | 17.48 ± 2.19 | 0.05 |
| | Start of ventilation | 22.66 ± 3.07 | 28.40 ± 3.07 | 0.05 |
| | Start of cardiac massage | 43.40 ± 5.03 | 19.27 ± 2.64 | 0.05 |
| Respiratory | Diagnosis of respiratory arrest | 19.17 ± 2.38 | 17.48 ± 2.19 | 0.05 |
| | Start of ventilation | 22.66 ± 3.07 | 19.13 ± 1.47 | 0.05 |

# CPR quality: common deficits

1. Slow compression rates
2. Frequent and lengthy pauses
3. Shallow compressions
4. Hyperventilation

# How are Compressions usually done

- In the real world CPR is poorly done:
  - Too slow
  - Too shallow (not deep enough)
- Likely related to fatigue

*Wik, 2005; Abella 2005; Sutton 2009*

# Ability to judge Compression Depth (unpublished)

Survey of lay public at the shopping mall

100 subjects in each group

What is 2 inches?

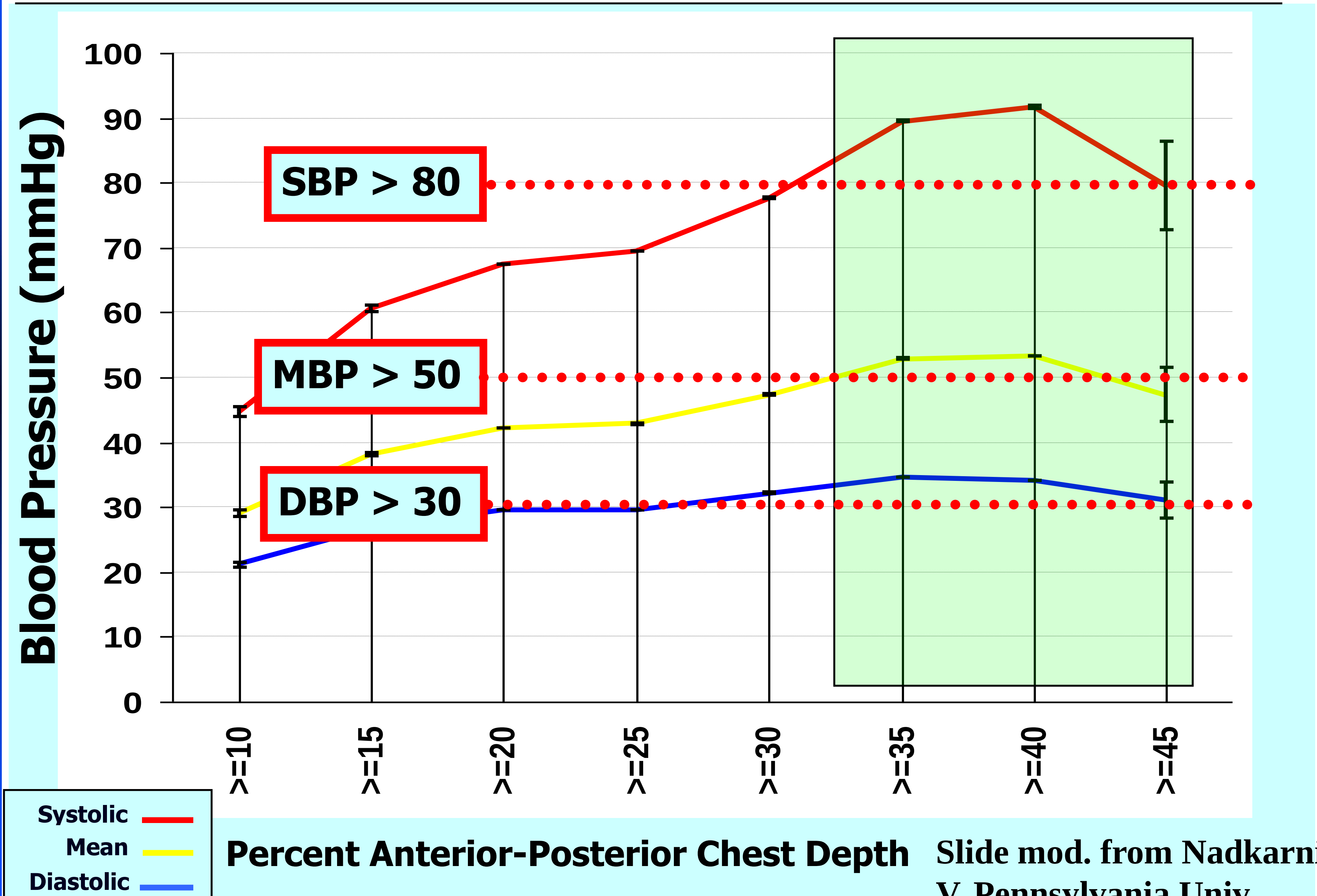
- 1.9” (Range 0.8 to 3.8)
- 40% were incorrect by > 0.5 inches

What is 5 centimeters?

- 4.27 cm (Range 0.58 to 12.55!!)
- 70% were incorrect by > 1.25 cm

Courtesy of Berg M; Mendelson, UA Resuscitation Research Group, 2010

Maher KO et al. Depth of sternal compression and intra-arterial blood pressure during CPR in infants following cardiac surgery. Resuscitation 2009;80:662




Slide mod. from Nadkarni V. Pennsylvania Univ

## Niles DE et al. Comparison of relative and actual chest compression depths during cardiac arrest in children, adolescents, and young adults. Resuscitation 2012;83:320 (n=35, 21 PICU, 14 Emerg Dpt)

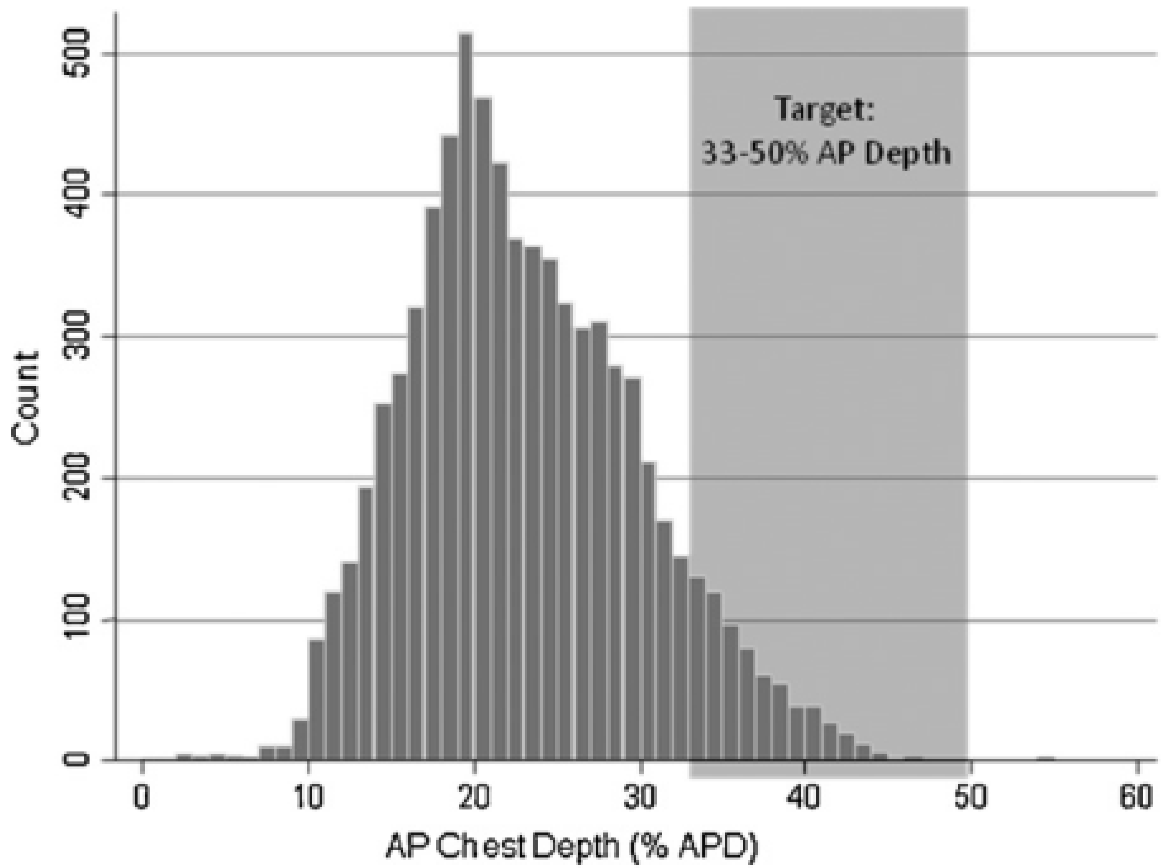



Fig. 1.
Corrected depth relative to APD for pre-puberty group (2005 AHA Guideline target depth 33–50% AP depth).

# Niles DE et al. Comparison of relative and actual chest compression depths during cardiac arrest in children, adolescents, and young adults. Resuscitation 2012;83:320 (n=35, 21 PICU, 14 Emerg Dpt)

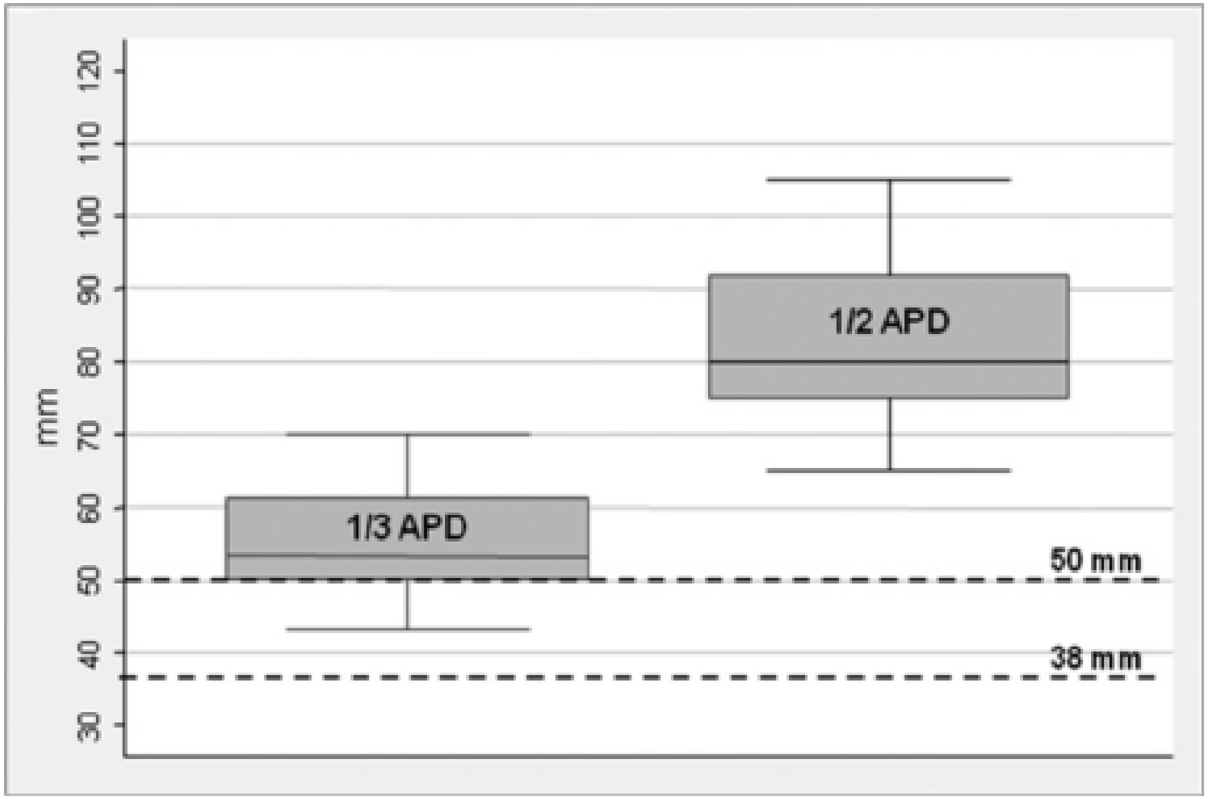
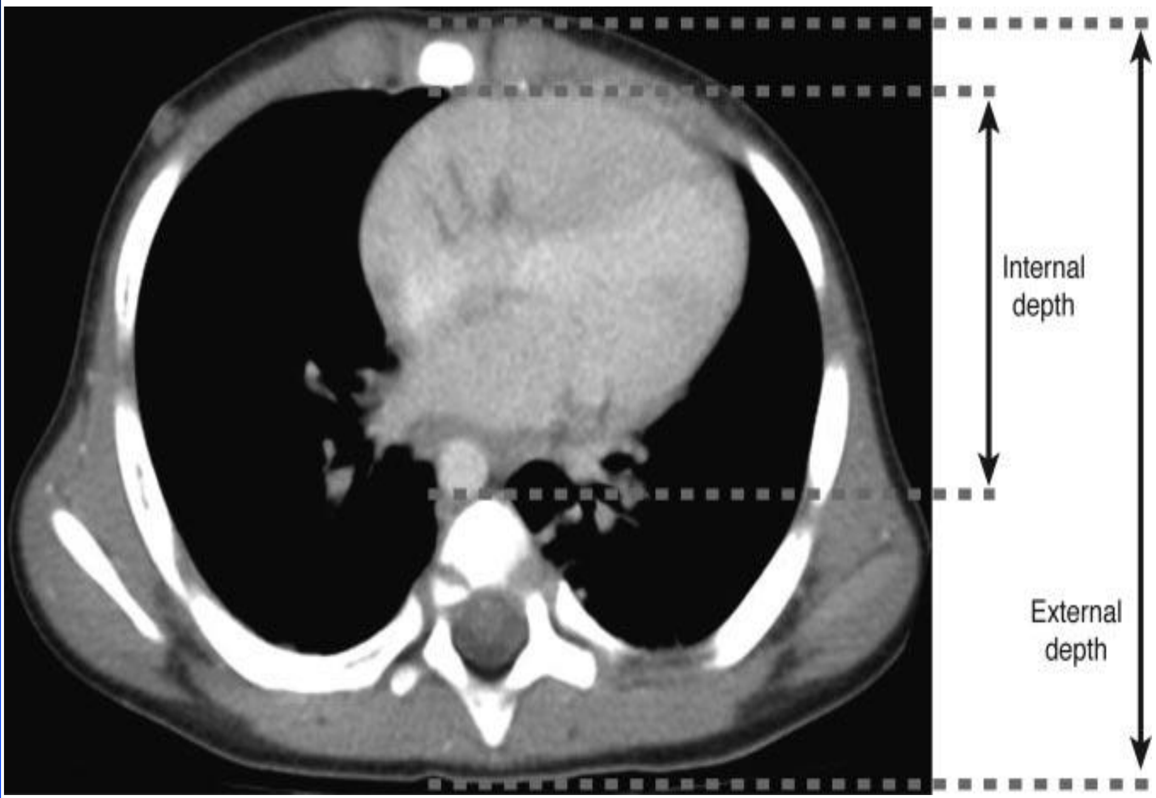



**Fig. 2.**
Boxplots displaying the distribution of anthropometric chest depths relative to APD for 8–14 years pre-puberty subjects (1/3 APD; 1/2 APD). The dotted lines represent the location of the 2005 adult (≥38 mm) and 2010 pediatric and adult (≥50 mm) chest compression minimum guideline targets. The upper adjacent value and the lower adjacent value described in horizontal lines (whiskers) indicate the highest and lowest values within 1.5 IQR from the 75th percentile and 25th percentile, respectively.

# Braga MS, et al. Estimation of optimal CPR chest compression depth in children by using computer tomography. Pediatrics 2009,124:e69-e74




Targeting 1/2 AP results in internal depth **< 10mm** in **94%** of children 3m to 8 yrs

# Sutton RM et al. AHA CPR Quality Targets are Associated with Improved Art BP During Pediatric CA. Resuscitation 2013;84:168 (n=9; 4156 CCs; ROSC 2)

**AHA depth achieved 26.2%**
**AHA rate achieved 83.7%**
**SBP ≥80 achieved 60.5%**
**DBP ≥ 30 achieved 61.6%**

| Subject | Age (yrs) | Depth (mm) | Rate (CC/min) | Force (kg) | NFF (%) | SBP (mmHg) | DBP (mmHg) | MAP (mmHg) |
|---|---|---|---|---|---|---|---|---|
| 1 | 16 | 47 (42, 51) | 125 (118, 133) | 30 (26, 34) | 17 | 38 (34, 44) | 18 (17, 20) | 25 (23, 27) |
| 2 | 13 | 36 (32, 39) | 113 (107, 120) | 33 (28, 38) | 14 | 82 (74, 95) | 34 (31, 37) | 50 (45, 56) |
| 3 | 14 | 29 (26, 30) | 113 (109, 118) | 23 (21, 26) | 7 | 82 (78, 87) | 32 (30, 34) | 49 (47, 51) |
| 4 | 14 | 40 (38, 41) | 111 (105, 118) | 31 (29, 36) | 30 | 65 (58, 73) | 29 (27, 32 ) | 41 (38, 45) |
| 5 | 17 | 20 (18, 23) | 109 (100, 122) | 36 (29, 38) | 11 | 93 (84, 104) | 28 (24, 33) | 50 (45, 57) |
| 6 | 15.5 | 31 (29, 33) | 103 (97, 109) | 29 (27, 32) | 15 | 75 (58, 91) | 28 (26, 31) | 44 (37, 50) |
| 7 | 17 | 44 (39, 49) | 107 (100, 113) | 50 (43, 56) | 15 | 93 (76, 123) | 22 (19, 25) | 45 (38, 57) |
| 8 | 1.75 | 30 (27, 33) | 104 (100, 109) | 25 (20, 28) | 4 | 80 (75, 85) | 37 (36, 40) | 52 (50, 54) |
| 9 | 6.4 | 28 (26, 30) | 115 (109, 122) | 33 (29, 44) | 1 | 181 (166, 204) | 62 (59, 64) | 101 (95, 111) |

Data presented as median (IQR).

## Sutton RM et al. AHA CPR Quality Targets are Associated with Improved Art BP During Pediatric CA.
## Resuscitation 2013;84:168 (n=9; 4156 CCs; ROSC 2)

| | SBP ≥ 80 | DBP ≥ 30 |
|---|---|---|
| Rate Only ≥ 100 CC/min | 1.32 (1.04, 1.66) * | 2.15 (1.65, 2.80) † |
| Depth Only ≥ 38mm | 1.04 (0.63, 1.71) | 0.97 (0.52, 1.79) |
| Rate and Depth | 2.02 (1.45, 2.82) † | 1.48 (1.01, 2.15) // |

* p=0.02;
† p<0.001;
|| p=0.042.

# What about interruptions

205 interruptions during 20 cardiac arrest events

52% for provider switch

duration: median 3.4s; IQR 2 – 6.3s

**Provider switch accounts for**
**41 to 67%**
**of total no flow time !**

duration: median 22.4s; IQR 13.9 – 34.4s

14.6% other / undetermined

duration: median 4.9s; IQR 1.6 – 12.2s

**Sutton RM et al, Resuscitation 2009, 80, 1259.**

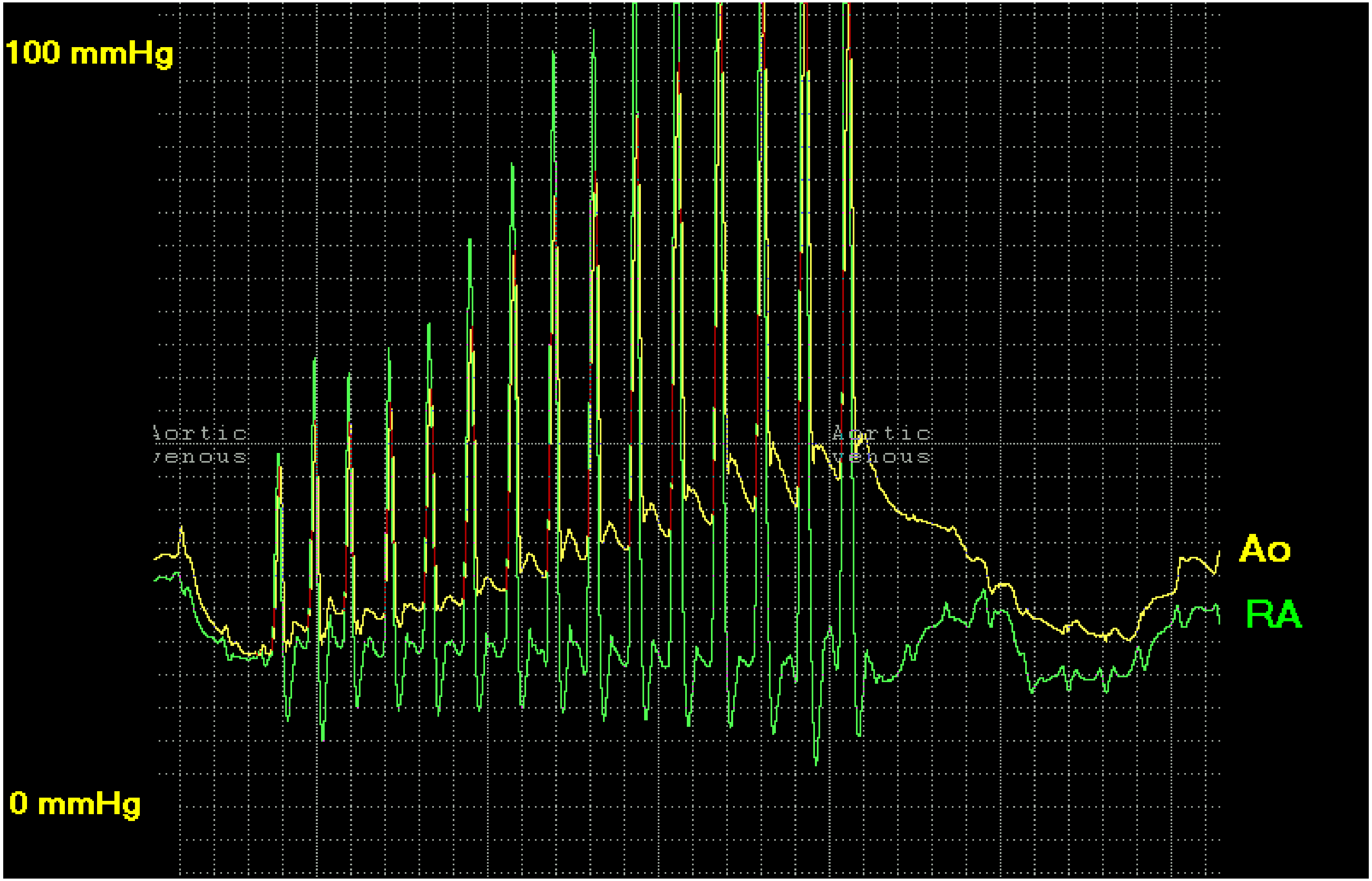
# Interruption of compressions

## Worse hemodynamics

- Lower # of compressions/min
- Decrement in Aortic DBP
- Lower LV MBF
- Can result in worse outcomes
- Minimize interruptions!

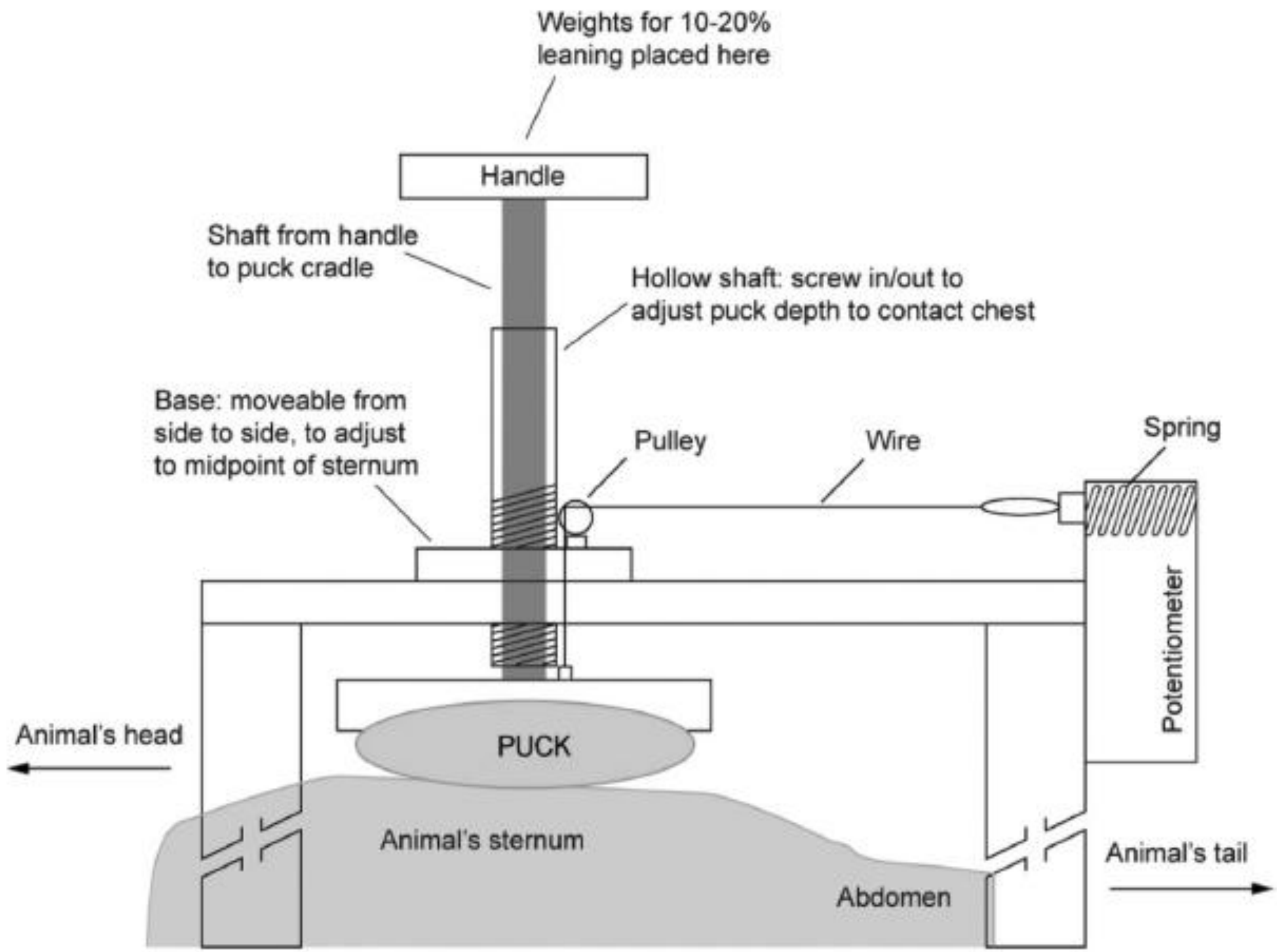
Berg, *Circulation* 2001; Kern, *Circulation* 2002

# Interruptions of CC and CPP




Sarver Heart Center Resuscitation Research Team, Courtesy of Berg M, Arizona, Univ

# Zuercher M et al. Leaning during CC impairs CO and LF MBF in piglet cardiac arrest. Crit Care Med 2010;38:1141



# Effect of “Leaning”- piglets model
## Pressures during CPR

| | No Lean | 10 % | 20 % |
|---|---|---|---|
| AoS | 87 ± 4 | 86 ± 4 | 87 ± 5 |
| RAD | 9 ± 2 | 11 ± 2* | 13 ± 3* |
| CPP | 22 ± 5 | 19 ± 7# | 17 ± 6# |

*P<0.001, #P<0.05

Zuercher M, Crit Care Med 2010;38:1141

# Effect of “Leaning” – piglets model

## Flows during CPR

| | No Lean | 10 % | 20 % |
|---|---|---|---|
| MBF | 0.40 ± 0.34* | 0.24 ± 0.22 | 0.19 ± 0.12 |
| CI | 1.78 ± 0.77* | 1.21 ± 0.61 | 0.95 ± 0.32 |

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

Zuercher M, Crit Care Med 2010;38:1141

## Sutton RM et al. First quantitative analysis of CPR quality during I-H cardiac arrests of young children (< 8yrs). Resuscitation 2014;85:70

8 CC events resulted in 285 thirty-second epochs of CPR (15,960 CCs).
Percentage of epochs achieving targets:

**54% (153/285) for rate,**

**19% (54/285) for depth,**

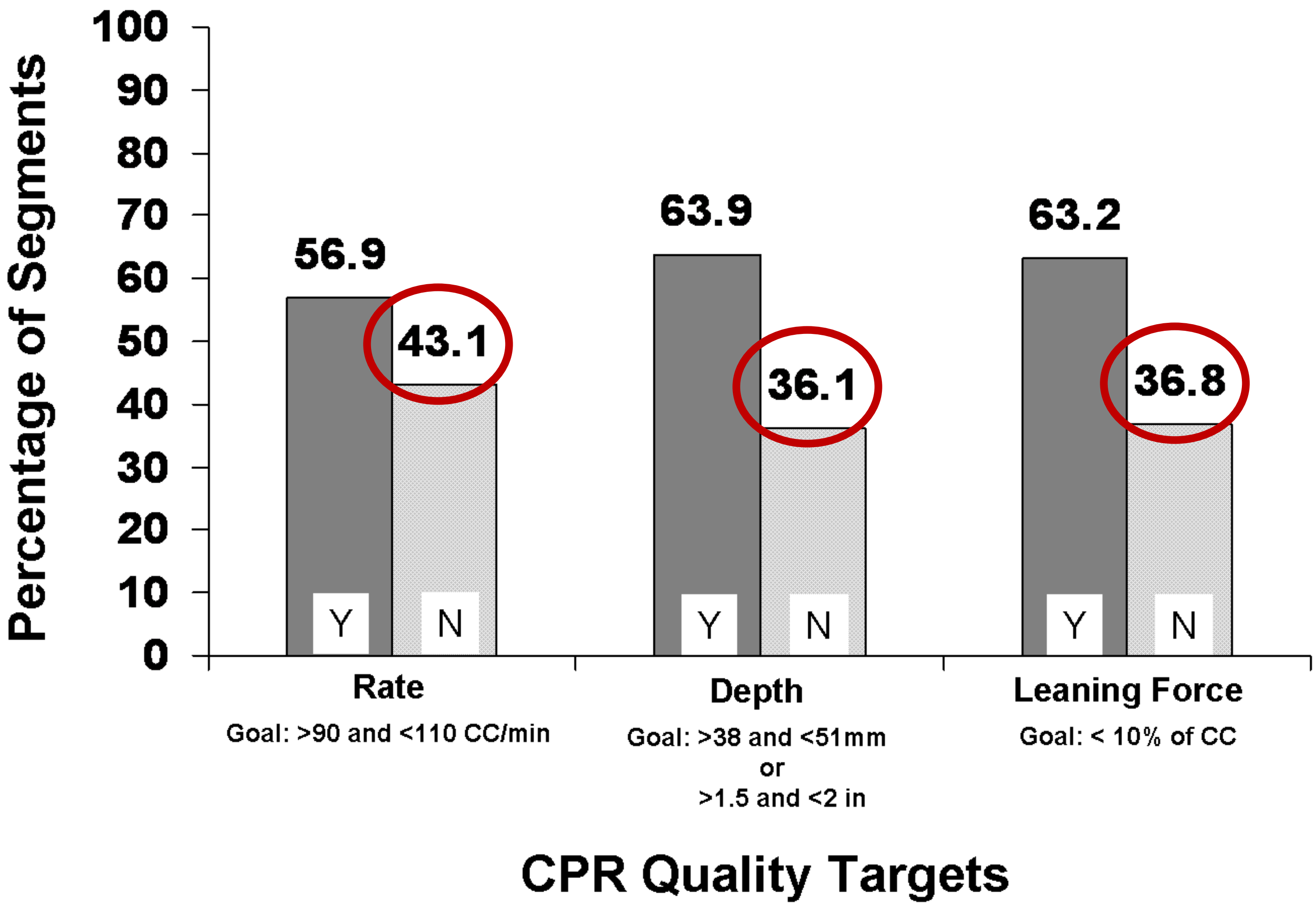
**79% (226/285) for leaning,**

**8% (24/285) for excellent CPR.**

The median percentage of epochs per event achieving targets increased with audiovisual feedback

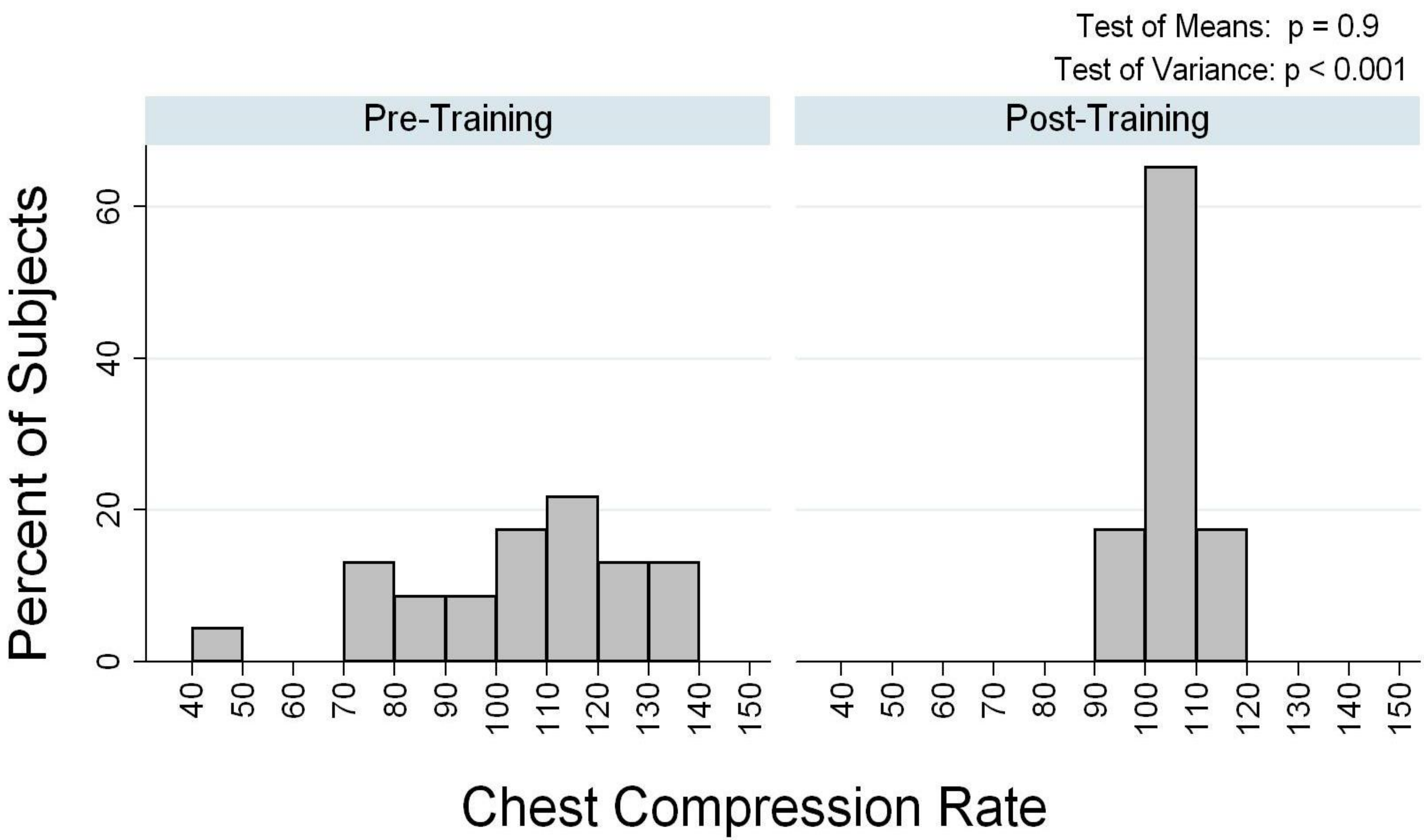
for rate [88 (IQR: 79, 94) vs. 39 (IQR 18, 62) %; p=0.043]
for excellent CPR [28 (IQR: 7.2, 52) vs. 0 (IQR: 0, 1) %; p=0.018]

# Leaning is common during I-H pediatric CPR and decreased with automated corrective feedback.
# 20 PCA, n= 37.396 CC



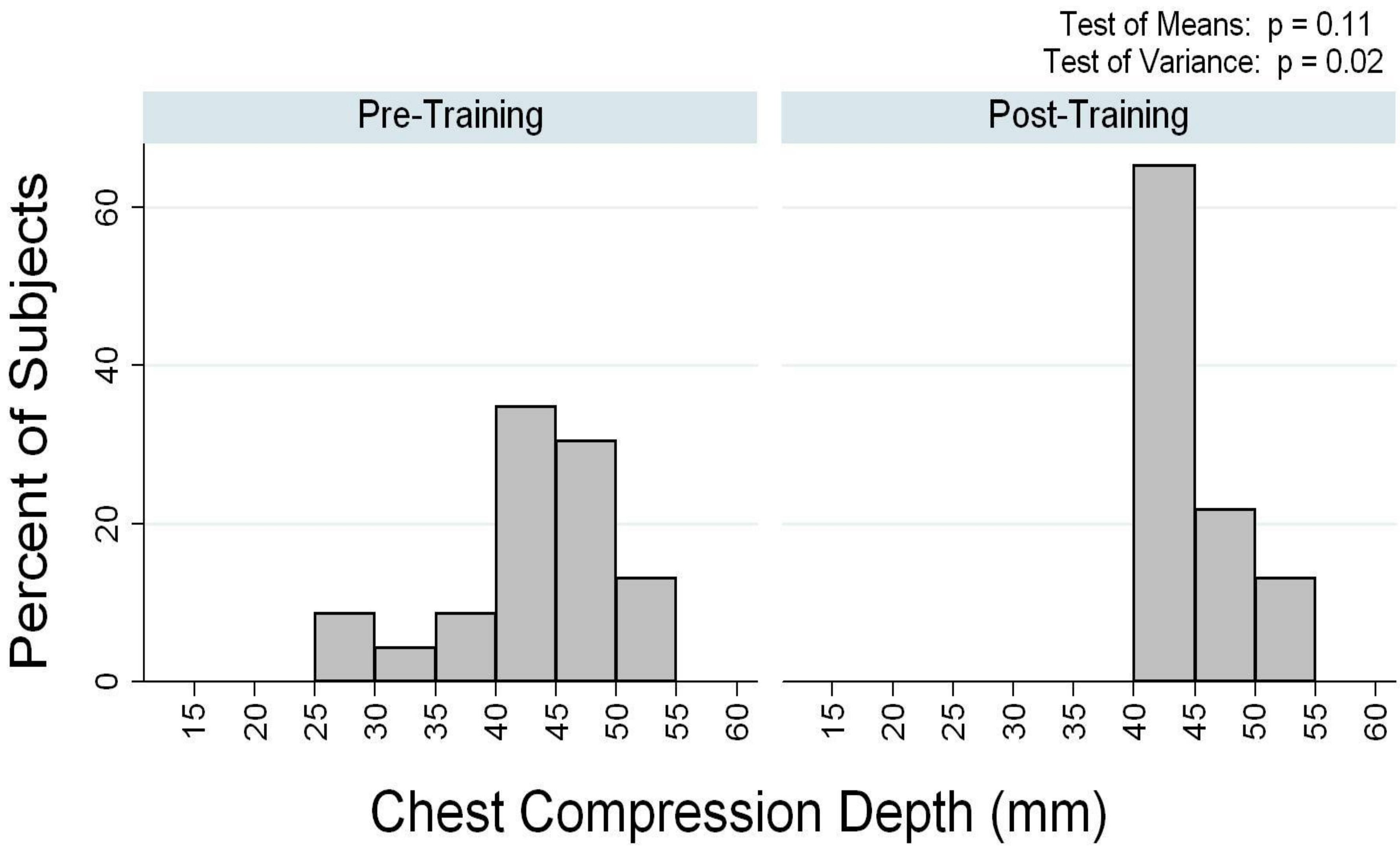

Niles D et al  Resuscitation 2009, 80, 553.

# Rate of CC and training




Sutton et al. PCCM, 2010

# CC depth and training




**Sutton et al. PCCM, 2010**

# Is Rescue Breathing Necessary for Pediatric Bystander CPR?

# Arterial Blood Acid Base balance

| | pH | pCO2 | SaO2 |
|---|---|---|---|
| **BASELINE** | | | |
| Compress only | 7.46 | 38 | 95% |
| Compress & Vent | 7.46 | 40 | 94% |
| | | | |
| **After 10 m CPR** | | | |
| Compress only | 7.40 | 34 | 75% |
| Compress & Vent | 7.50* | 21* | 91%* |

Berg RA, Circulation 1997: porcine model, 26 animals

# Coronary Sinus Acid Base balance

| | pH | $pCO_2$ | $SaO_2$ |
|---|---|---|---|
| BASELINE | | | |
| Compress only | 7.40 | 45 | 62% |
| Compress & Vent | 7.38 | 49 | 59% |
| | | | |
| After 10 m CPR | | | |
| Compress only | 7.19 | 64 | 10% |
| Compress & Vent | 7.13 | 74 | 9% |

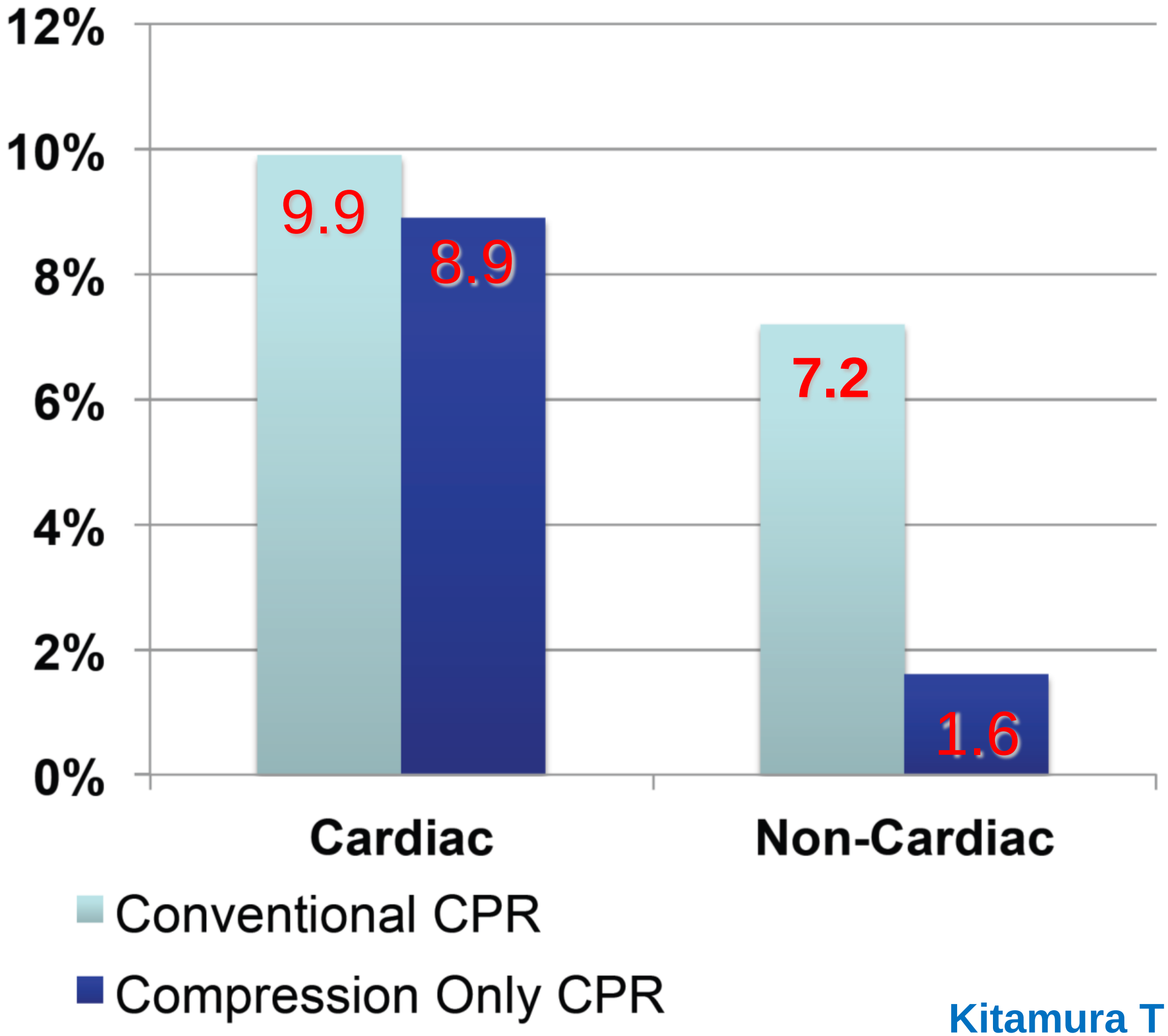
Berg RA, Circulation 1997: porcine model, 26 animals

# Improved Outcome with Ventilation

- 40 immature swine (~ 11kg)
- ETT clamped to loss of pulse
- Return Of Spontaneous Circulation
  - Compressions only = 4/10
  - Compressions and vent = 10/10

Berg RA, Circulation, 2000, 101:1743

# Bystander CPR for Pediatric OHCA: conventional vs C-C only (n = 5170) Favourable outcome




**Cardiac Cause: 29%**
**vs.**
**Non-Cardiac Cause: 71%**
**Conv 30%**
**CC only 17%**

Kitamura T et al. Lancet 2010;375:1347

# Ventricular Fibrillation - Three Phases

**Electrical Phase (Defibrillate)**

**Hemodynamic Phase (Perfuse)**

**Metabolic Phase (Needs Energy)**

.

# Pediatric Defibrillation, how much energy is needed?

**The AHA recommended defibrillation energy dose for pediatric VF is 2 J/kg**

Guidelines, Circulation 2000

**But: ERC 4 J/Kg**

# 2 J/kg Dose

- Based on single study of brief VF using monophasic defibrillation in IH CA
- Less effective in defibrillation
  - Especially in ‘longer’ duration VF

# Pediatric defibrillation dose

| Berg MD *et al*, Resuscitation 2005 | Gutgesell HP *et al*, Pediatrics 1976 |
|---|---|
| Shocks studied=14 | Shocks studied=57 |
| 2 J/kg ±10J | 2 J/kg ±10J |
| Monophasic Damped Sinusoidal Waveform | Monophasic Damped Sinusoidal Waveform |
| Out-of-hospital arrest | In-hospital arrest |
| Prolonged down-time | Brief down-time |

# Out-of-hospital Cardiac Arrest: results

| | |
|---|---|
| Cardiac arrests: | 151 children |
| Ventricular Fibrillation: | 13 children (9%) |
| Received "pediatric dose" shock : | 11 children |
| Total shocks studied: | 14 shocks |

Median minimum down-time = 11 minutes

Berg MD *et al*, Resuscitation 2005

# Out-of-hospital Cardiac Arrest: results

**Only 7/14 (50%) shocks were successful in terminating VF in this study**

**vs 52/57 (91%) shocks in Gutgesell, *Pediatrics*, 1976 p=0.001**

**Berg MD *et al*, Resuscitation 2005**

# 2 J/kg Often Ineffective

## Animal Data

Berg MD et al. Attenuating the defibrillation dose decreases postresuscitation myocardial dysfunction in a swine model of pediatric VF. *Ped Crit Care Med,* 2008;9:429

Berg RA et al. Attenuated adult biphasic shocks compared with weight-based monophasic shocks in a swine model of prolonged pediatric VF. *Resuscitation*, 2004;61:189.

## Human Data

Berg MD et al, *Resuscitation*, 2005;67:63

Rodriguez-Nunez A et al, *Critical Care*, 2006;10:R113 (18%)

Tibballs J et al, *Ped Crit Care Med*, 2011;12:14 (42%)

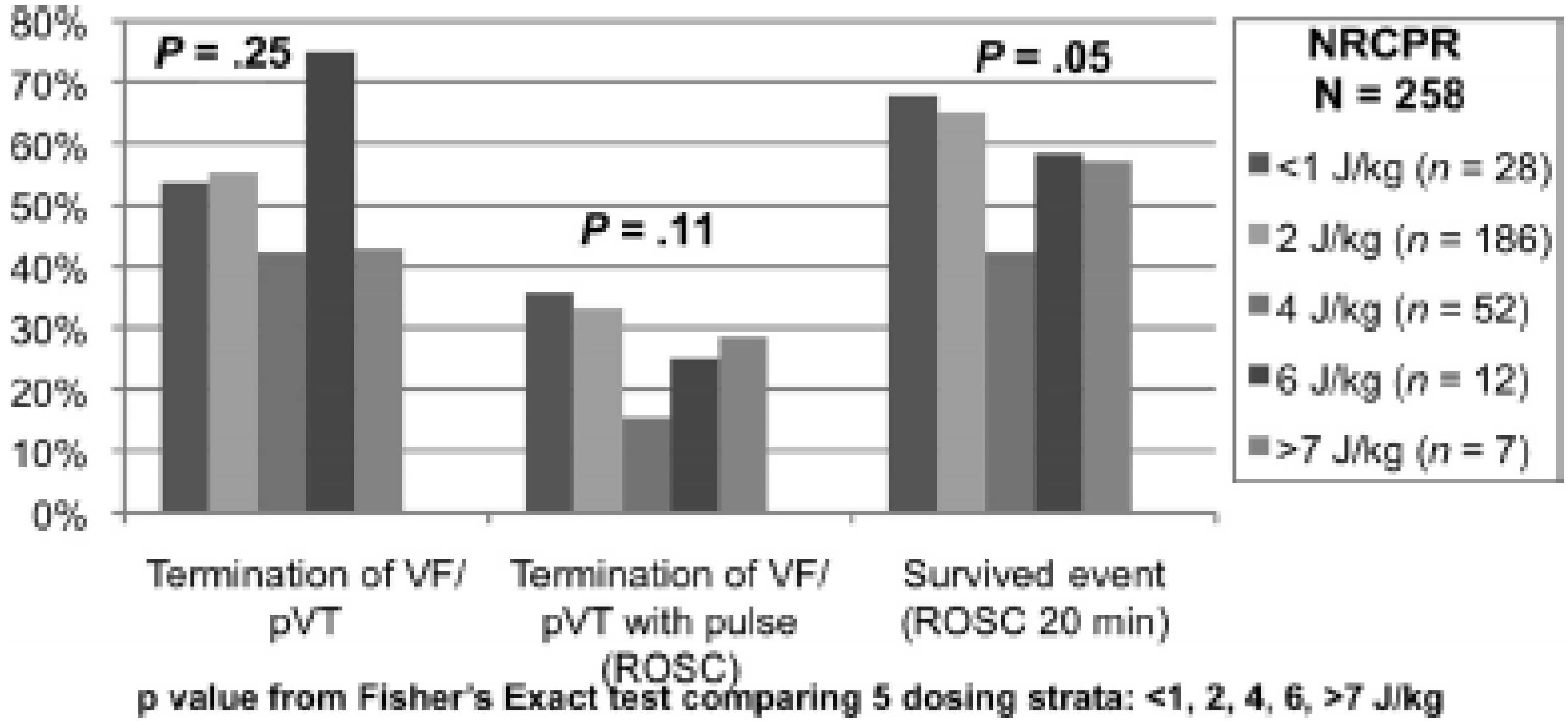
# Meaney PA et al Effect Of Defibrillation Energy Dose During In-Hospital Pediatric Cardiac Arrest Pediatrics, 2011;127:e16

In-hospital arrest (NRCPR): 266 patients with 285 events. 186 shocks were at 2 J/kg (± 10J). 143 patients with primary VF

Termination of first VF after one shock for 152/285 (53%), 173/285 (61%) survived the event, 61/266 (23%) survived to discharge

Termination of VF with 2 J/kg ± 10J was MUCH less frequent than among historic controls (55% versus 91%, $P<0.001$).

# Meaney PA et al, Effect Of Defibrillation Energy Dose During In-Hospital Pediatric Cardiac Arrest Pediatrics, 2011;127:e16



# Defibrillation dose

Not all VF is the same, may need unique approaches

- Brief duration (witnessed) is easier to defibrillate
- Long duration (O-OH, no bystander-CPR) more resistant to defibrillation

# Pediatric Resuscitation

**New *post-arrest care link* in the chain of survival**

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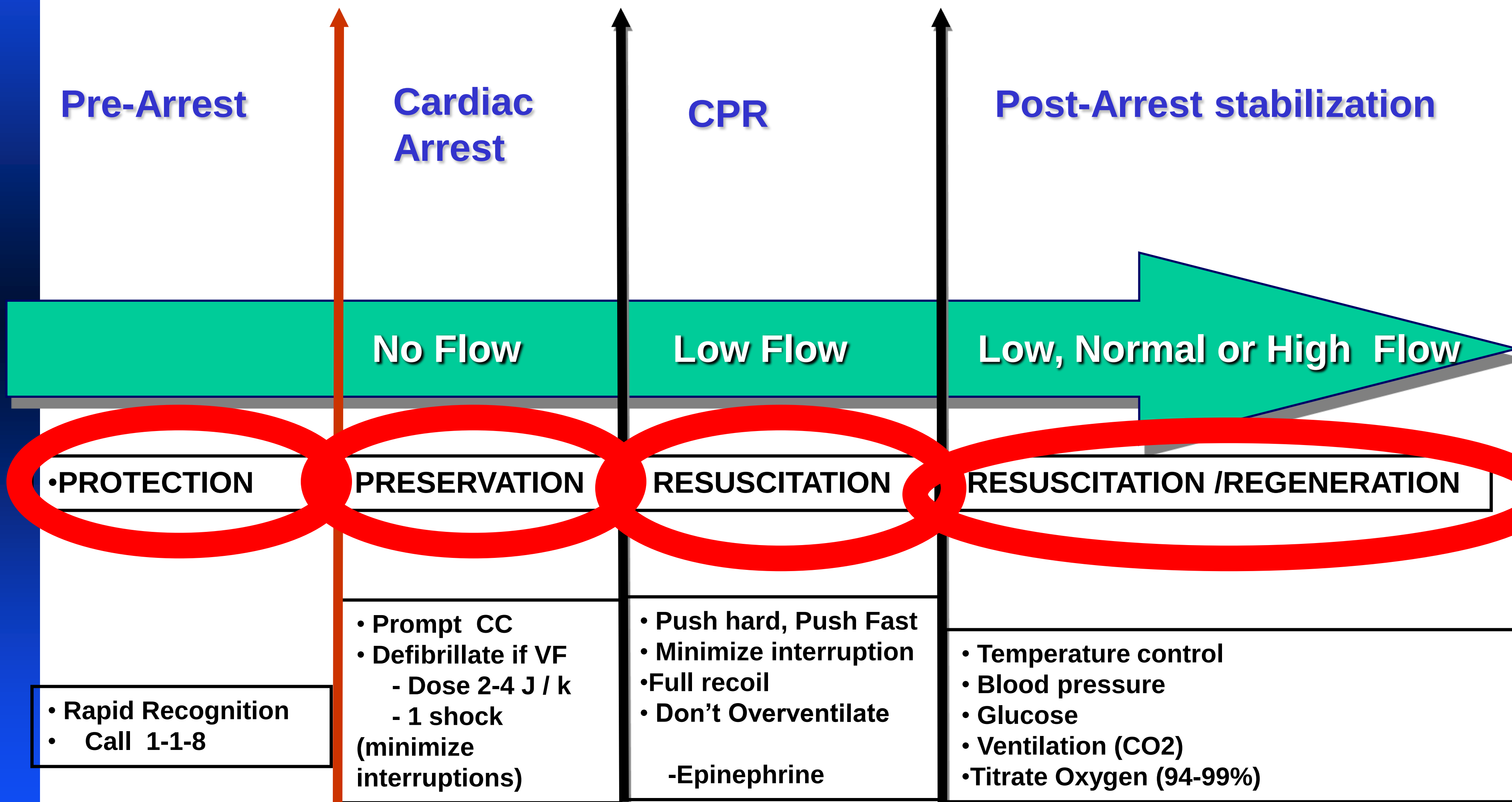
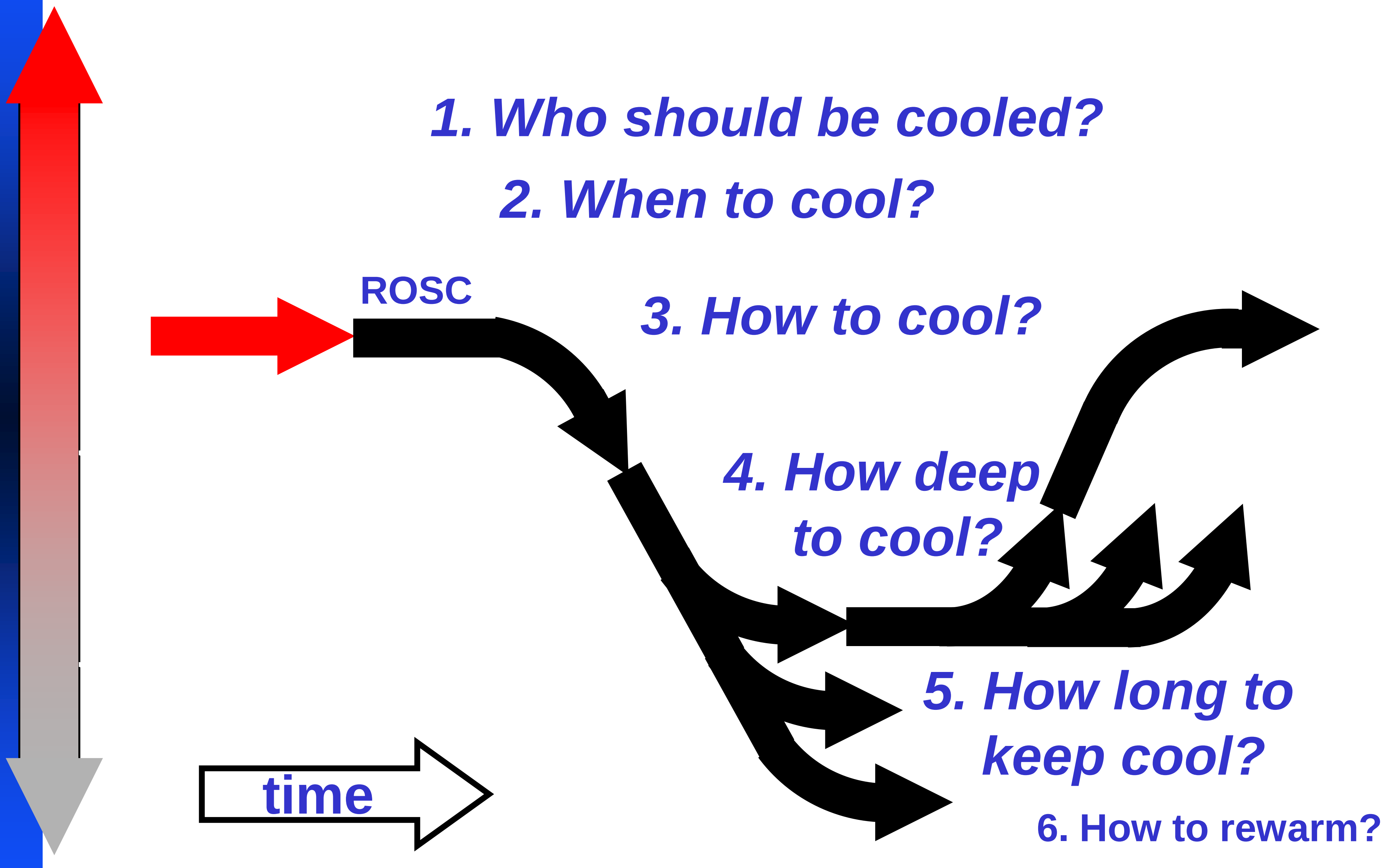
# The final picture




Slide modified from V. Nadkarni, MD, Univ of Pennsylvania, Philadelphia

# Questions about hypothermia




Slide modified from T. van den Hoek, MD, U Chicago

# What about hypothermia in children?

The value of or best approach to cooling children after cardiac arrest is unknown. Extrapolation from adult studies (HACA and others) is used in some centers.

"Therapeutic hypothermia (32°C to 34°C) may be considered for children who remain comatose after resuscitation from cardiac arrest (Class IIb, LOE C)."

"The ideal method and duration of cooling and rewarming are not known."

# Aknowledgments

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