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Pediatric Cardiac Arrest

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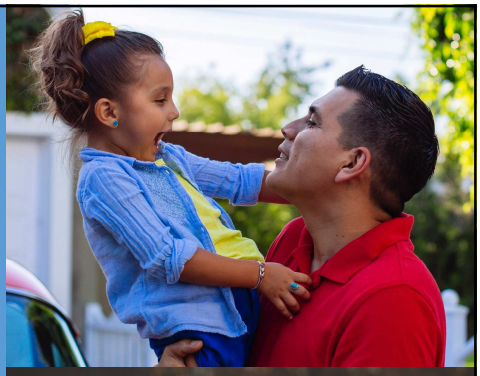

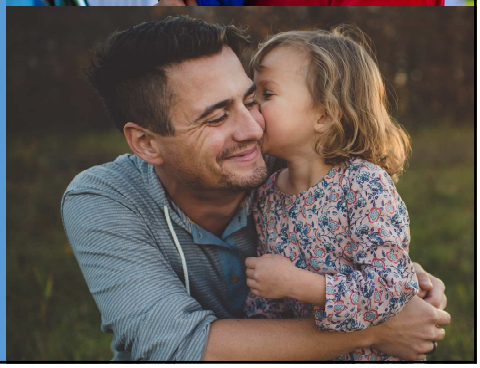

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Presenter Disclosure Information

Erin Powell, MD

Pediatric Cardiac Arrest

FINANCIAL DISCLOSURE:
None

UNLABELED/UNAPPROVED USES DISCLOSURE:
None

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Outline

- Epidemiology of Pediatric Cardiac Arrest
- Monitoring the effectiveness of CPR
- When conventional CPR fails
- Post-resuscitation care
- Outcomes

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Epidemiology of Pediatric Cardiac Arrest

- Relatively uncommon compared with adult cases
- ~16,000 children in the United States experience an OHCA each year
- ~5,800 experience an IHCA each year
  - >10-fold higher rate if cardiovascular disease.
  - Higher rates in CICUs (4% to 6% of admissions) than in PICUs (2% to 4%)
- ~2000 patients younger than 25 years will die from a sudden cardiac event each year in the United States

Immediate cause of arrest	
Arrhythmia (VF, ventricular tachycardia, supraventricular tachycardia)	21 (19)
Hypotension/hypoperfusion	51 (46)
Hypoxia/respiratory decompensation	62 (54)

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Epidemiology of Pediatric Cardiac Arrest

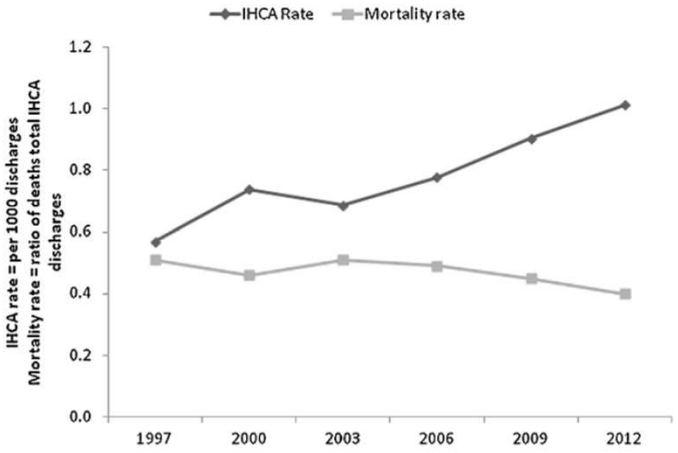

Fig. 1. In-hospital cardiac arrest (IHCA) and mortality rates in children for each cohort from 1997 through 2012.

The epidemiology and outcomes of pediatric in-hospital cardiopulmonary arrest in the United States during 1997 to 2012☆

Paul A. Martinez[a], Balagangadhar R. Totapally[a,b,*]

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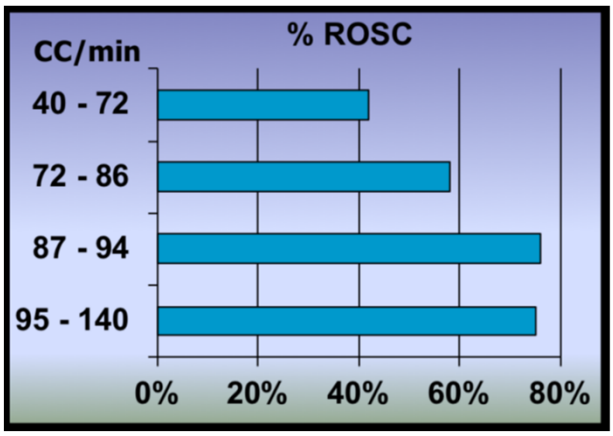
High Quality CPR

1. **Chest compression rate**
2. Appropriate depth
3. Full recoil of the chest
4. Limited time off the chest
5. Avoid hyperventilation



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Abella BS. Circ 2005; 111:428-34

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High Quality CPR

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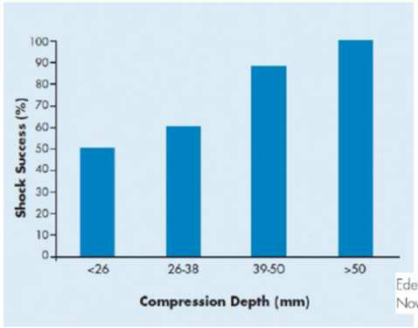
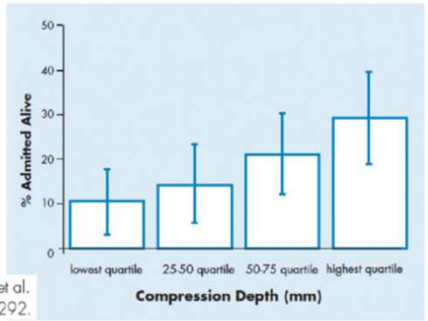


Edelson DP, et al. *Resuscitation*. 2006 Nov;71(2):137–45.

Minute	1	2	3	4	5
Correct Chest Compres-sion Depth	79.7%	24.9%	18.0%	17.7%	18.5%

*Ochoa FJ, et al. Resuscitation 1998 Jun;37(3(:149-52



Based on: Kramer-Johansen J, et al. *Resuscitation*. 2006;71:283–292.

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High Quality CPR

1. Chest compression rate
2. Appropriate depth
3. **Full recoil of the chest**
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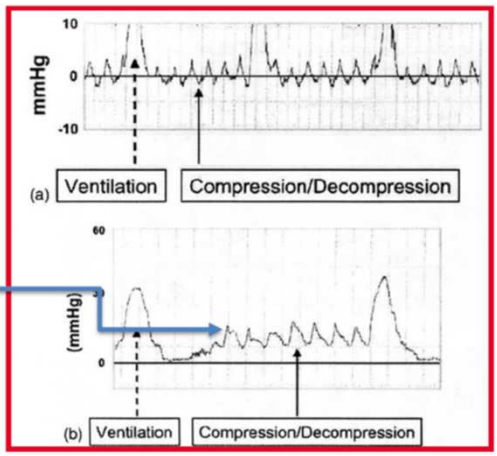

Almost half of patients had residual pressure in chest after recoil

Aufderheide T, Resus 2005; 64:353-

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High Quality CPR

1. Chest compression rate
2. Appropriate depth
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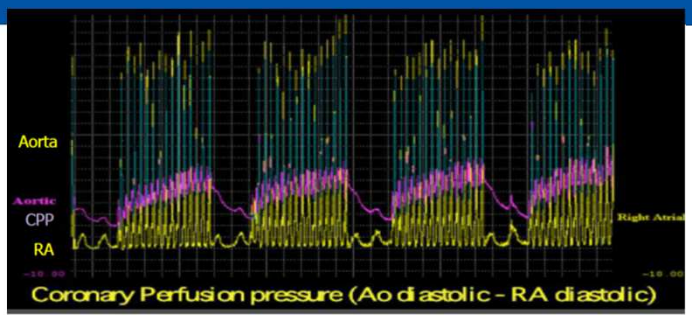

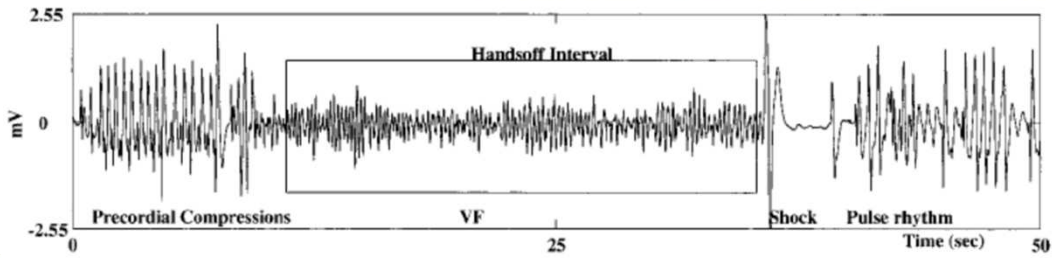

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So how do we do?

- Chest compression quality metrics often do not meet 2015 American Heart Association guidelines. Guideline compliance for rate and depth in children less than 18 years is poor, with the greatest difficulty in achieving chest compression depth targets in younger children. (*Pediatr Crit Care Med* 2018; 19:421–432)

TABLE 3. Summaries of Cardiopulmonary Resuscitation 60-Second Epochs and Compliance With American Heart Association Metric Targets

	Total	< 1 yr	1 to < 8 yr	8 to < 18 yr	p	
Events (*n*)	112	38	42	32		
CCs (*n*)	196,669	52,215	92,260	52,194		
60-s epochs (*n*)	2,046	592	936	518		
Epoch summaries, median (IQR)						
CC fraction (%)	93 (76–100)	88 (61–98)	94 (79–100)	94 (85–100)		
CC rate (CC/min)	117 (110–125)	119 (110–129)	117 (110–124)	117 (110–123)		
CC depth (cm)	3.6 (2.4–5.0)	2.3 (1.9–3.0)	3.8 (2.9–4.6)	5.5 (4.0–6.5)		
Maximum release velocity (mm/s)	217 (154–323)	147 (117–195)	217 (171–280)	366 (258–440)		
Epoch compliance, *n* (%)						
CC fraction	1,469 (72)	360 (61)	696 (74)	413 (80)	< 0.001	
CC rate	1,130 (55)	271 (46)	543 (58)	316 (61)	< 0.001	
CC depth[a,b]	635 (31)	103 (17)	286 (30)	246 (48)	< 0.001	
Absolute[c]		49 (8)	163 (17)		< 0.001	
CC fraction and CC rate	848 (42)	186 (31)	407 (44)	255 (49)	< 0.001	
CC fraction and CC depth[a,b]	501 (25)	72 (12)	217(23)	212 (41)	< 0.001	
Absolute[c]		37 (6)	137 (15)		< 0.001	
CC rate and CC depth[a,b]	395 (19)	48 (8)	195 (21)	152 (29)	< 0.001	*
Absolute[c]		19 (3)	120 (13)		< 0.001	
CC fraction, CC rate, and CC depth[a,b]	384 (19)	32 (5)	151 (16)	201 (39)	< 0.001	
Absolute[c]		14 (2)	103 (11)		< 0.001	

CC = chest compression, IQR = interquartile range.
[a]Using Guideline ≥ 1/3 Anterior-Posterior chest depth for < 8 yr: ≥ 3.4 cm for < 1 yr and ≥ 4.4 cm for 1 to < 8 yr.
[b]Using ± 10% Guideline absolute depth for 8 to < 18 yr is 4.5–6.6 cm.
[c]Using secondary ± 10% Guideline absolute depth for < 8 yr: 3.6–4.4 cm for < 1 yr and 4.5–5.5 cm for 1 to < 8 yr.
Differences in compliances analyzed using χ^2 analysis.

Collaborative Investigators

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2015 PALS Updates

- Targeting a specific end-tidal CO2 (ETCO2) threshold to improve chest compression technique
- Use of invasive hemodynamic monitoring during
- CPR to titrate to a specific systolic/diastolic blood pressure to improve outcomes
- Reliability of intra-arrest prognostic factors to predict outcome

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Part 12: Pediatric Advanced Life Support
2015 American Heart Association Guidelines Update for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

Allan R. de Caen, Chair; Marc D. Berg; Leon Chameides; Cheryl K. Gooden; Robert W. Hickey; Halden F. Scott; Robert M. Sutton; Janice A. Tijssen; Alexis Topjian; Elise W. van der Jagt; Stephen M. Schexnayder; Ricardo A. Samson

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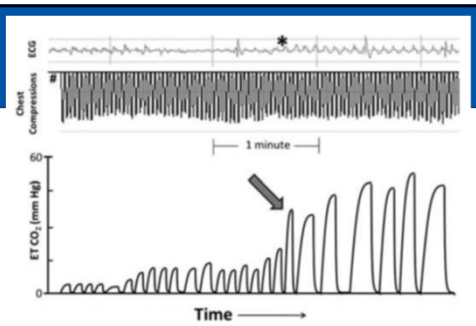
2015 PALS Updates



- **Targeting ETCO2 threshold**
- Invasive hemodynamic monitoring
- Intra-arrest prognostic factors

- ETCO2 monitoring may be considered to evaluate the quality of chest compressions, but specific values to guide therapy have not been established in children.
- Minimizes interruptions of CPR for pulse checks
- If ETCO2 is <15 mm Hg, efforts should focus on improving CPR quality, particularly improving chest compressions and ensuring that the victim does not receive excessive ventilation.

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2015 PALS Updates

- Targeting ETCO2 threshold
- **Invasive hemodynamic monitoring**
- Intra-arrest prognostic factors

- For patients with invasive hemodynamic monitoring in place at the time of cardiac arrest, it may be reasonable for rescuers to use blood pressure to guide CPR quality (Class IIb, LOE C-EO).
- Mean diastolic blood pressure ≥25 mm Hg during CPR in infants and ≥30 mm Hg in children ≥1 year old was associated with 70% greater likelihood of survival to hospital discharge and 60% higher likelihood of survival with a favorable neurological outcome.

Association Between Diastolic Blood Pressure During Pediatric In-Hospital Cardiopulmonary Resuscitation and Survival

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2015 PALS Updates

- Targeting ETCO2 threshold
- Invasive hemodynamic monitoring
- **Intra-arrest prognostic factors**

- Worse prognosis with OHCA,
  - age less than 1 year
  - longer durations of cardiac arrest
  - presentation with a nonshockable rhythm
- Worse prognosis with IHCA,
  - age greater than 1 year
  - longer durations

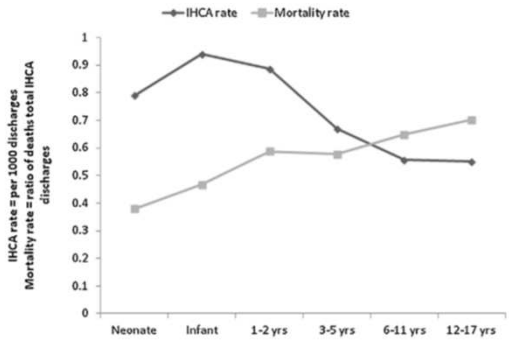

Fig. 2. In-hospital cardiac arrest (IHCA) and mortality rates by age group for each cohort from 1997 through 2012.

Martinez and Totapally. Resuscitation. 2016;105;177–181.

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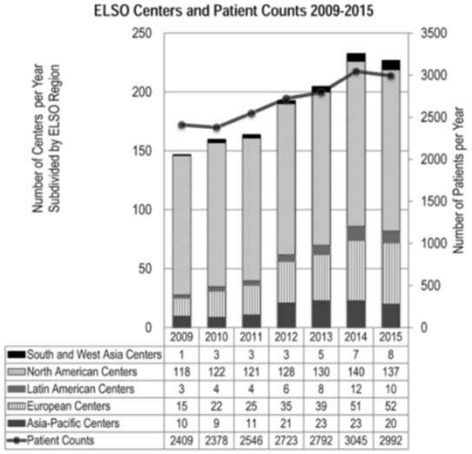
When conventional resuscitation fails… ECPR

- Sustained or repetitive arrest events without ROSC for > 20 minutes?



	2009	2010	2011	2012	2013	2014	2015
South and West Asia Centers	1	3	3	3	5	7	8
North American Centers	118	122	121	128	130	140	137
Latin American Centers	3	4	4	6	8	12	10
European Centers	15	22	25	35	39	51	52
Asia-Pacific Centers	10	9	11	21	23	23	20
Patient Counts	2409	2378	2546	2723	2792	3045	2992

Figure 1. Number of reporting ELSO center and patient counts, 2009–2015.

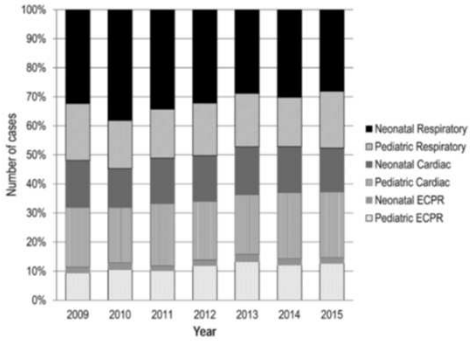


Figure 3. Trends in ECLS support type, 2009–2015.

Barbaro et al. ASAIO J. 2017 Jul/Aug;63(4):456-463.

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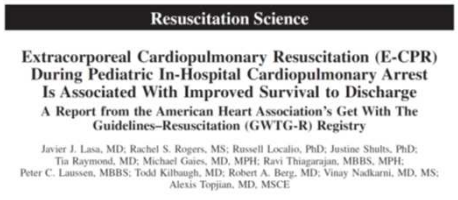
Pediatric CCPR vs. ECPR

- Age:
  - <1 year for both groups
- Underlying diagnosis:
  - E-CPR - surgical cardiac illness
  - C-CPR - medical noncardiac illness
- First documented rhythm:
  - E-CPR - PEA (41% versus 32%)
  - C-CPR - bradycardia (49% versus 32%).

Table 9. Characteristics of ECPR, 2011–2015

Variable, N (%)	ECPR Cases N = 1,828
Arrest location	
Operating room	116 (6)
Intensive care unit	1310 (72)
Emergency department	56 (3)
Ward	87 (5)
During transport	24 (1)
Outside hospital	37 (2)
Other location	127 (7)
Missing	71 (4)
Witnessed arrest	1,723 (94)



Resuscitation Science

Extracorporeal Cardiopulmonary Resuscitation (E-CPR) During Pediatric In-Hospital Cardiopulmonary Arrest Is Associated With Improved Survival to Discharge

A Report from the American Heart Association's Get With The Guidelines–Resuscitation (GWTG-R) Registry

Javier J. Lasa, MD; Rachel S. Rogers, MS; Russell Localio, PhD; Justine Shults, PhD; Tia Raymond, MD; Michael Gaies, MD, MPH; Ravi Thiagarajan, MBBS, MPH; Peter C. Laussen, MBBS; Todd Kilbaugh, MD; Robert A. Berg, MD; Vinay Nadkarni, MD, MS; Alexis Topjian, MD, MSCE

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Post-resuscitation care

- Use of **targeted temperature management** to improve outcomes
- Use of a **targeted Pao2 strategy** to improve outcomes
- Use of a **specific Paco2 target** to improve outcomes
- Use of **parenteral fluids and inotropes and/or vasopressors** to maintain targeted measures of perfusion such as blood pressure to improve outcomes
- Use of **electroencephalograms (EEGs)** to accurately predict outcomes
- Use **of any specific post–cardiac arrest factors** to accurately predict outcomes

ASAIO Journal 2017 Pediatric Circulatory Support

Pediatric Extracorporeal Life Support Organization Registry International Report 2016

Ryan P. Barbaro,* Matthew L. Paden,† Yigit S. Guner,‡ Lakshmi Raman,§ Lindsay M. Ryerson,¶ Peta Alexander,‖ Viviane G. Nasr,# Melania M. Bembea,** Peter T. Rycus,†† and Ravi R. Thiagarajan,‡ on behalf of the ELSO member centers

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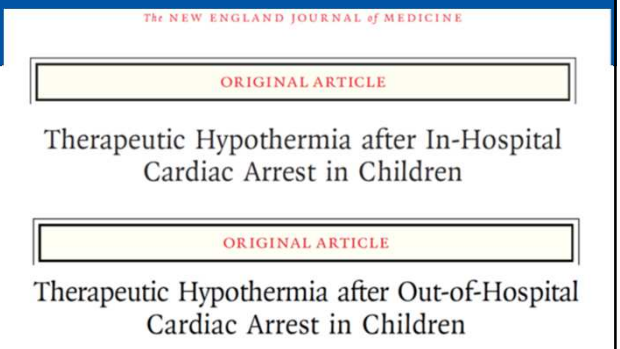
Post-resuscitation care

- **Targeted temperature management**
- Targeted Pao2
- Targeted Paco2
- Targeted measures of perfusion
- EEG
- Post–cardiac arrest factors


The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Therapeutic Hypothermia after In-Hospital Cardiac Arrest in Children

ORIGINAL ARTICLE

Therapeutic Hypothermia after Out-of-Hospital Cardiac Arrest in Children

- No difference in survival with good functional with therapeutic hypothermia compared to normothermia
- Fever (temperature 38°C or higher) should be aggressively treated after ROSC (Class I, LOE B-NR).

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Post-resuscitation care

- Targeted temperature management
- **Targeted Pao2**
- Targeted Paco2
- Targeted measures of perfusion
- EEG
- Post–cardiac arrest factors

- Normoxemia (Pao2 > 60 mm Hg but < 300 mm Hg) when compared with hyperoxemia (Pao2 > 300 mm Hg) after ROSC was associated with improved survival to pediatric ICU discharge.
- Goal SpO2 >94%, <100%

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Pediatric Extracorporeal Life Support Organization Registry International Report 2016

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Post-resuscitation care

- Targeted temperature management
- Targeted Pao2
- **Targeted Paco2**
- Targeted measures of perfusion
- EEG
- Post–cardiac arrest factors

- Hypercapnia (Paco2 >50 mm Hg) was associated with worse survival to hospital discharge.
- In other types of pediatric brain injury, hypocapnia is associated with worse clinical outcomes.

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Post-resuscitation care

- Targeted temperature management
- Targeted Pao2
- Targeted Paco2
- **Targeted measures of perfusion**
- EEG
- Post–cardiac arrest factors

- Three small observational studies involving pediatric IHCA and OHCA demonstrated worse survival to hospital discharge when children were exposed to post-ROSC hypotension.
- After ROSC, we recommend that parenteral fluids and/or inotropes or vasoactive drugs be used to maintain a SBP > 5% for age.
- When appropriate resources are available, continuous arterial pressure monitoring is recommended to identify and treat hypotension.

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Post-resuscitation care

- Targeted temperature management
- Targeted Pao2
- Targeted Paco2
- Targeted measures of perfusion
- **EEG**
- Post–cardiac arrest factors

- EEGs performed within the first 7 days after pediatric cardiac arrest may be considered in prognosticating neurologic outcome at the time of hospital discharge but should not be used as the sole criterion.

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Post-resuscitation care

- Targeted temperature management
- Targeted Pao2
- Targeted Paco2
- Targeted measures of perfusion
- EEG
- **Post–cardiac arrest factors**

- Pupillary reactivity and lower lactate levels at 12-24h are associated with improved survival.
- The reliability of any 1 variable for prognostication in children *after* cardiac arrest has not been established. Practitioners should consider multiple factors when predicting outcomes in infants and children who achieve ROSC after cardiac arrest.

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Outcomes of Pediatric Cardiac Arrest

- Outcomes after OHCAs are better among children than adults, but still poor.
  - ~20% of children had ROSC prior to ED arrival (~8% for infants to ~35% for adolescents)
  - ~10% survived to hospital discharge and infants with lowest survival rates
  - Survival did not improve from 2007-2012
- Survival in children with an IHCA have improved significantly from 2000-2009 (~15% to 35%-43%)
  - ~80% with a favorable neurological outcome
  - Survival to hospital discharge is higher for surgical cardiac patients (37%-52%) than medical cardiac (28%-43%) or noncardiac (23%) patients

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Outcomes of Pediatric Cardiac Arrest

- 29% of patients survived to hospital discharge
  - 27% for C-CPR patients compared with 40% in the E-CPR group
  - Favorable neurological outcome occurred in 18% of the C-CPR patients and 27% of the E-CPR patients
- Survival rates decrease over the first 15 minutes of CPR, yet patients who received E-CPR had no difference in survival across CPR durations.
  - Survival for patients receiving >35 minutes of C-CPR was only 15.9% (compared to <15 minutes was 44.1%).
  - ~25% of surgical cardiac patients survived to discharge after >35 minutes of C-CPR compared with only 10% of medical noncardiac patients

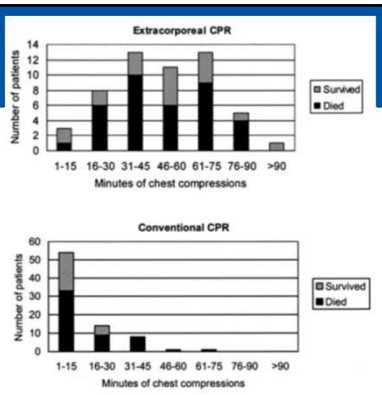

Table 1. ECLS Cases and Survival to Discharge, 1989–2017

	Number of Cases	Survived ECLS N (%)	Survived to Hospital Discharge N (%)
Neonatal			
Respiratory	30,062	25,297 (84)	22,040 (73)
Cardiac	7,243	4,697 (65)	2,988 (41)
ECPR	1,554	1,048 (67)	641 (41)
Pediatric			
Respiratory	8,162	5,487(67)	4,699 (58)
Cardiac	9,479	6,482 (68)	4,844 (51)
ECPR	3,469	1,995 (58)	1,444 (42)
Total	59,969	45,006 (75%)	36,656 (61%)

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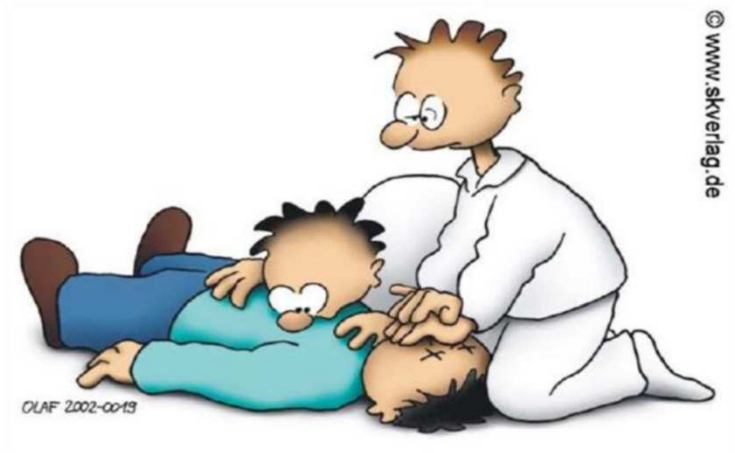
Thank you! And don't do this



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