eCPR bei Kindern

Was ist klinisch/präklinisch machbar?

Ass Prof Dr Gudrun Burda

eCPR bei Kindern

Panta Rhei

Kein Konflikt of Interest

Inhalt

cCPR vs eCPR

Basics zur ECMO bei Kindern

Outcome

Ist alles Machbare auch sinnvoll?

Anforderungen an ECMO-Zentrum

cCPR

GUIDELINES 2000

. Strukturiertes Vorgehen

. Erkennen und Management des Kritisch Kranken Kindes

. 15:2 Qualität

. Teammanagement – Teamtraining

. Daten-Registry

OHCA/IHCA – Fall 1

17-Jähriger Schüler

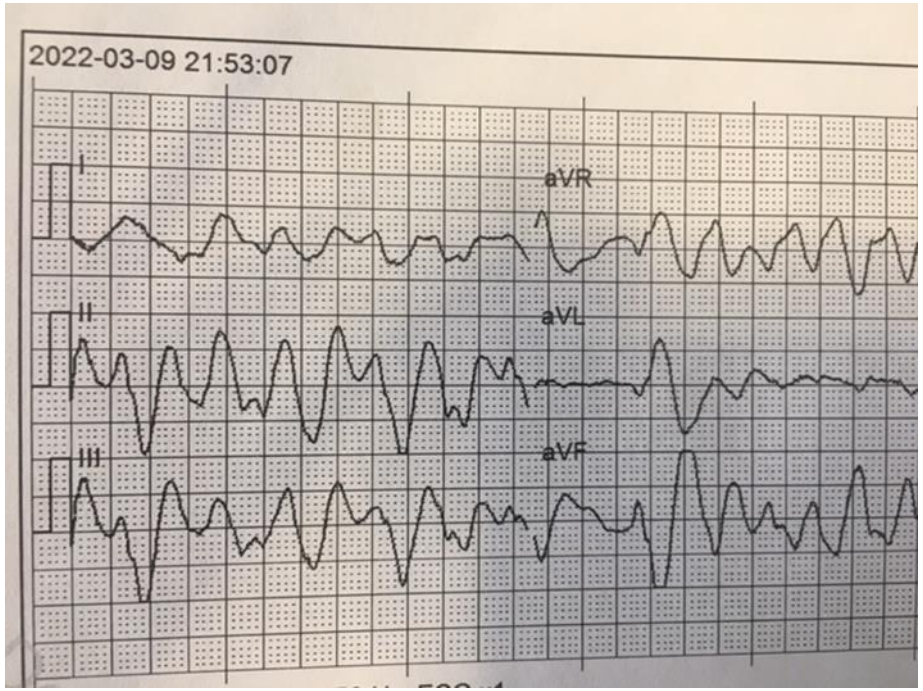
Von der Mutter vor Toilette im Erbrochenen liegend vorgefunden

Letzter nachweislicher Kontakt vor 10 min.

Alarm 21:36 – ROSC 22:04 - Einsatzende mit Transfer 23:30

Beteiligt: Familie, First Responder (3x), Polizei, Feuerwehr, RTW, SFZ, NEF

Intubiert, beatmet, pVK, 4 x Schock,Adrenalin Amioderon, Magnesium, Fenta, Midazolam, Rocuronium



OHCA/IHCA Fall 1

Puls pos. (20-30),

Blutdruckmessung (nmb-120/17)

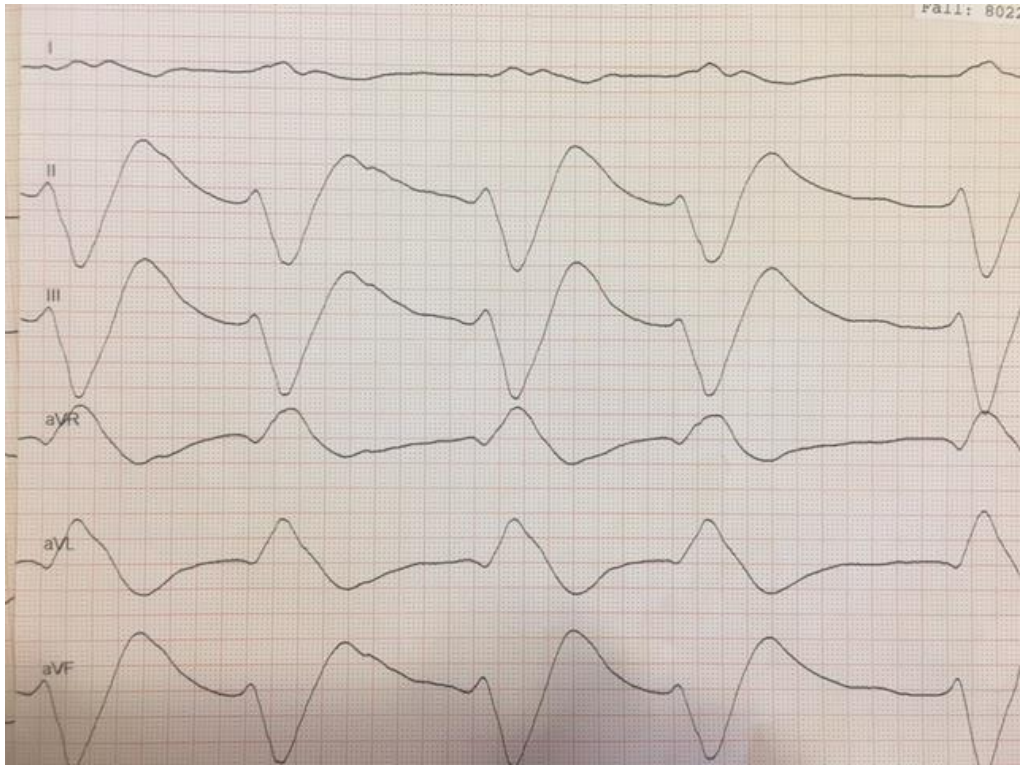
Temp 33°

pH7,2 pCO2 38, BE-8,2 ; Laktat 6,2; BZ 281

Dobutrex, Suprarenin, Amioderon, Esmolol

Herz-US sehr schlechte Funktion

Ursache ????????????



OHCA/IHCA – Fall 2

D.J. Mädchen 1 3/4 Jahre

Submersionsdauer unbekannt, 3/4h nach bemerkter Abgängigkeit apnoeisch und asystol im Fluss treibend aufgefunden

Unter Laienreanimation im PKW ins nahegelegene Spital gebracht

Kerntemperatur 20°

Transfer zum Aufwärmen 2h Reanimation

eCPR

Definition: Start einer VA-ECMO wenn unter cCPR Maßnahmen kein ROSC eintritt bzw. bis 20min nach ROSC mit LCO

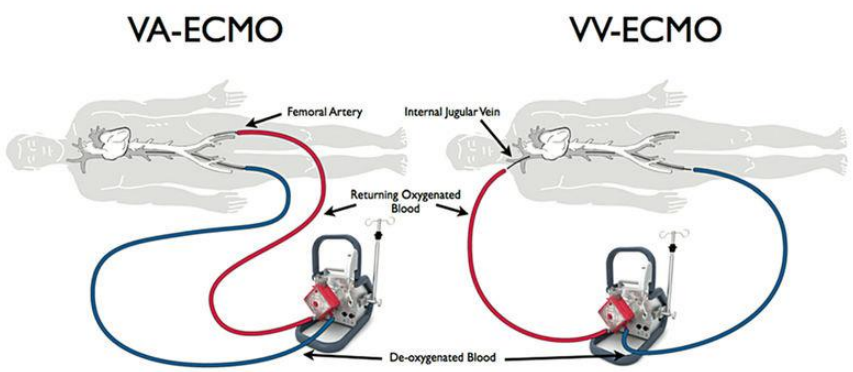
Ziel: ausreichend Kreislauf zu erreichen, Zeitgewinn Ursachen zu erkennen, Therapien zu beginnen, reversible Organversagen zu unterstützen und Bridging zum Kunstherz, TX oder Entscheidung zu ermöglichen.

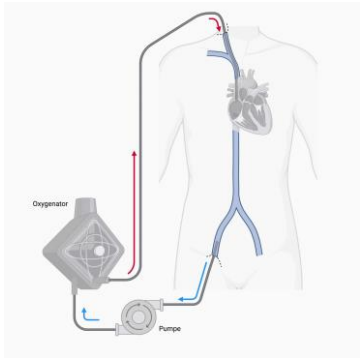
Defizite: Fehlen von randomisierten Studien

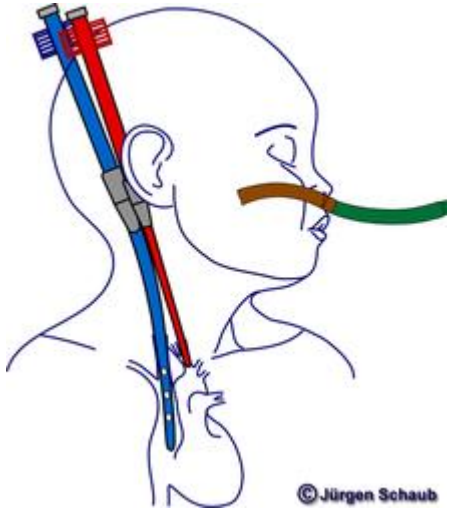
Benefit eCPR?

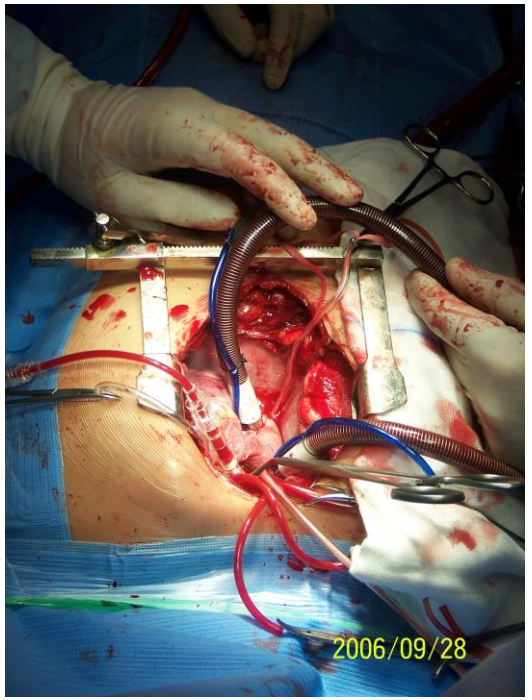
- senkt intrahospitale Mortalität
- Erholung d Herzens nach Hypoperfusion und Kompressionen
- Kreislaufstabilisierung verhindert Sekundärschäden
- max. Ausschöpfung der End-Organ Erholung
- Reduktion der Beatmung
. Reduktion von Vasopressoren
- Temperatur-Regulation

eCPR Basics - Zugang



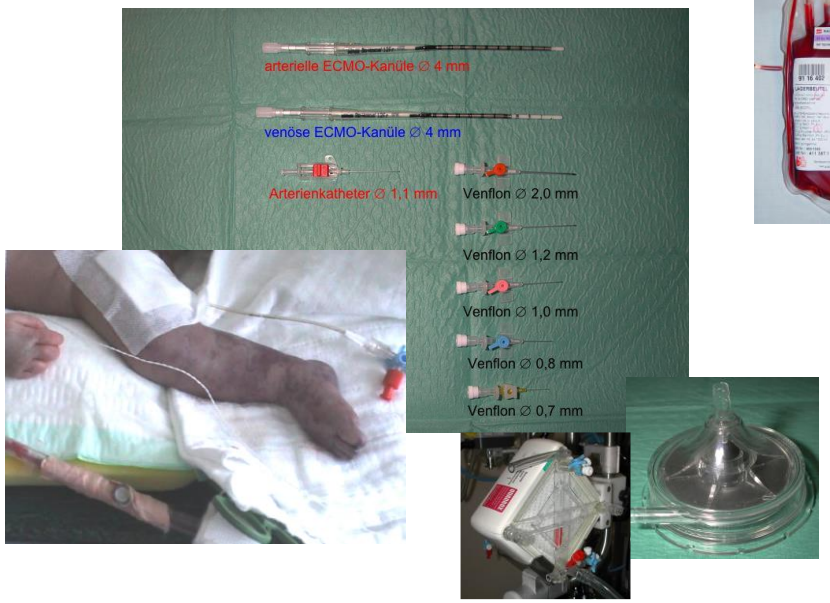


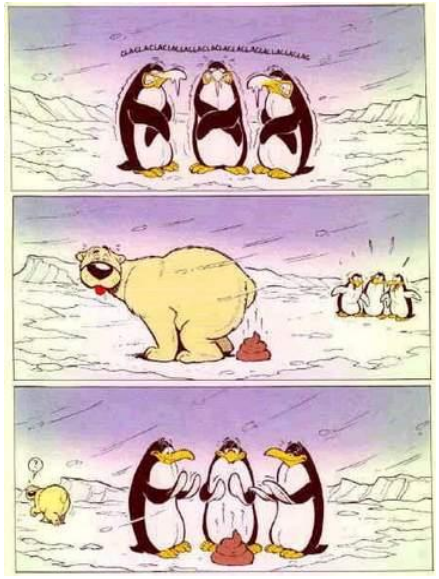




eCPR Basics – ECMO Kreislauf/Antrieb

eCPR Besonderheiten bei Kinder





Primingvolumen in Relation zu hoch
Zugang
Thrombose/Embolie
Hypothermie

Verdünnungseffekt

Antikoagulation

CO2 Auswaschung

eCPR Outcome
PICU 2000 – 2022
n=58

Diplomarbeit 2024
B.Handler

Alter: 38 GA – 18a
Gewicht: 2,5kg – 69,5 kg

Primäres Outcome **Verlassen d Spitals n=23**	**Mortalität**	**Gut**	**Schlecht**
	N=35 60,3%		
Sekundäres Outcome **Neurologie**		N=11 19%	N=11 19%

eCPR Outcome PICU 2000 – 2022 n=58

Diplomarbeit 2024
B.Handler

Diagnose

Alter: 38 GA – 18a
Gewicht: 2,5kg – 69,5 kg

	Prim Outcome	Sekundäres Outcome	
		Gut	**Schlecht**
Cardial n=38	N=16 42,1%	N=7 18,4%	N=9 23,7%
Pulmonal n=8	N=5 62,5	N=4	N=1
Trauma n=6	N=1 16,7%	N=0	N=1
Infektion n=4	N=0 0%	N=0	N=0

eCPR Outcome
PICU 2000 – 2022
n=58

Diplomarbeit 2024
B.Handler

Ort des Cardiac arrest

Statistisch errechnete Mortalitäts-Wahrscheinlichkeit

OHCA n=10	80%
IHCA n=48	56,3%

Extracorporeal Life Support Organization Registry International Report 2022: 100,000 Survivors

Neonatal Geburt – 28LT, Kinder 29LT-17LJ, Erwachsen > 18LJ

Pulmonal, Cardial, ECPR

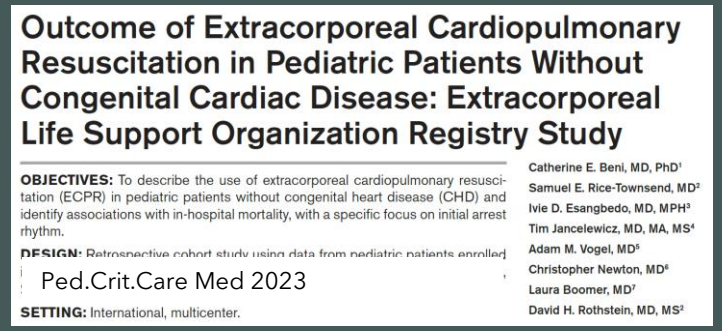
VV, VA, VVA, VP

Table 1. ECMO Case Counts, Center Counts, and Survival, 2009–2022

Age Group	Support Type	Runs	Centers	Survival to 24 Hours After ECMO Decannulation*	Survival to Hospital Discharge†
Adult	Respiratory	48,338	658	67.2% (32,008/47,663)	57.3% (27,701)
	Cardiac	45,830	634	62.6% (28,138/44,927)	44.2% (20,264)
	ECPR	14,097	504	44% (6,124/13,910)	29.5% (4,162)
Pediatric	Respiratory	8,495	421	74.5% (6,214/8,342)	63.8% (5,423)
	Cardiac	11,504	393	76.9% (8,621/11,213)	57.7% (6,636)
	ECPR	5,740	309	58.9% (3,311/5,617)	41.0% (2,355)
Neonatal	Respiratory	11,511	242	82.7% (9,327/11,277)	68.5% (7,888)
	Cardiac	6,911	264	71.5% (4,827/6,750)	48.3% (3,337)
	ECPR	2,142	181	67.5% (1,411/2,091)	44.3% (949)

*This excludes run records in which the patient was not reported as being discharged alive to home and for which the patient's time of death/discharge was not recorded.

†This is the percentage of patients discharged alive and off ECMO.



Outcome of Extracorporeal Cardiopulmonary Resuscitation in Pediatric Patients Without Congenital Cardiac Disease: Extracorporeal Life Support Organization Registry Study

OBJECTIVES: To describe the use of extracorporeal cardiopulmonary resuscitation (ECPR) in pediatric patients without congenital heart disease (CHD) and identify associations with in-hospital mortality, with a specific focus on initial arrest rhythm.

DESIGN: Retrospective cohort study using data from pediatric patients enrolled

SETTING: International, multicenter.

Catherine E. Beni, MD, PhD[1]
Samuel E. Rice-Townsend, MD[2]
Ivie D. Esangbedo, MD, MPH[3]
Tim Jancelewicz, MD, MA, MS[4]
Adam M. Vogel, MD[5]
Christopher Newton, MD[6]
Laura Boomer, MD[7]
David H. Rothstein, MD, MS[2]

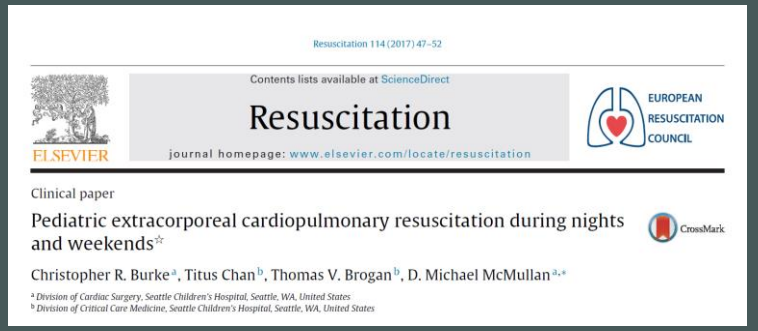
Ped.Crit.Care Med 2023

ASAIO Journal 2012

Reviews

Pediatric Outcomes After Extracorporeal Membrane Oxygenation for Cardiac Disease and for Cardiac Arrest: A Review

Ari R. Joffe,* Laurance Lequier,* and Charlene M.T. Robertson†



Resuscitation 114 (2017) 47–52

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

EUROPEAN RESUSCITATION COUNCIL

Clinical paper

Pediatric extracorporeal cardiopulmonary resuscitation during nights and weekends☆

Christopher R. Burke[a], Titus Chan[b], Thomas V. Brogan[b], D. Michael McMullan[a,*]

[a] Division of Cardiac Surgery, Seattle Children's Hospital, Seattle, WA, United States
[b] Division of Critical Care Medicine, Seattle Children's Hospital, Seattle, WA, United States

N=567 - ELSO
Resp.,ACD,Sepsis
IH- Mortaliät 59%
Höher :Trauma, Übergewicht
Besser: initial VT

Kum.ECMO hosp.survivor n=1755
45% (32%-79%)
eCPR (14 Studien 2000-2011) 49% (33%-79%)
Predictor f. Mortalität:
- non-CD
- Nierenversagen
- neurol.Komplikation
- niederer pH

N=53

59 vs 33 min CA-Start

eCPR

Clinical paper

Modeling severe functional impairment or death following ECPR in pediatric cardiac patients: Planning for an interventional trial

Francesca Sperotto[a,d,e,1], Kwannapas Saengsin[a,d,1], Amy Danehy[b,d],

Resuscitation2021

→ IHM 52% nach 6Mo 57%
p-ECMO 28 Tage Kontrolle

Special Issue: EuroELSO 2024

Perfusion

Perfusion
2024, Vol. 39(1S) 81S–94S
© The Author(s) 2024
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/02676591241236139
journals.sagepub.com/home/prf
Sage

The approach to extracorporeal cardiopulmonary resuscitation (ECPR) in children. A narrative review by the paediatric ECPR working group of EuroELSO

HA Mensink,[1] A Desai,[2] M Cvetkovic,[3] M Davidson,[4] A Hoskote,[3] M O'Callaghan,[3] T Thiruchelvam[3] and PP Roeleveld[1]

Table 1. Factors associated with outcomes of ECPR. CA: cardiac arrest, CHD: congenital heart disease, AKI: acute kidney injury, RRT: renal replacement therapy, IHCA: in-hospital cardiac arrest, OHCA: out-of-hospital cardiac arrest, CCPR: conventional cardiopulmonary resuscitation. The factors 'after ECPR' are not risk factors for mortality or survival, but essential components to ECPR care.

	Adverse Risk Factors for mortality and/or poor neurological outcome	Protective factors for improved survival
Before ECMO (baseline characteristics)	Single-ventricle physiology[28–31] Non-cardiac disease[32,33] Acquired heart disease[27] Higher complexity of CHD[28] Prematurity[33] Younger age (<12 months)[34] Chromosomal abnormalities[35] Neurologic comorbidity[17] Trauma[36] Obesity[36] Gastro-intestinal comorbidity[27] Technology dependence[27]	Two-ventricle physiology[28–31] Cardiac disease [17,37,38] White race[36,39] Post-cardiac surgery[27]
Cardiac arrest and CPR	OHCA Unwitnessed CA[40] Long duration of CCPR[41] CCPR interruptions[42] CCPR location outside ICU[27] High lactate[27,43] Acidosis, pH <7.01[28] Hypercarbia[44] Sodium bicarbonate bolus[32] Calcium[45] Blood-primed ECMO circuit[35]	IHCA Short duration of CCPR[41] Open-chest compressions[27] CA in catheterisation lab[24] PH >7.17[39] Neck/RCA cannulation[28,38]
During ECPR	Time to normal lactate[43] Normalization of lactate[27] AKI/Renal failure[28,32,33,35,38,39,46] RRT[31,34] Fluid overload[47] ECMO duration[30] Neurologic complications[28,31,34,35,38,39,48]	Early diagnosis and management of underlying cause[49–52]
After ECPR	Transition of care	Neurodevelopmental follow-up

Prediktor

Predictors of survival for pediatric extracorporeal cardiopulmonary resuscitation
A systematic review and meta-analysis

Nitish Sood, BS[a,*], Anish Sangari, BS[a], Arnav Goyal, BS[a], J. Arden S. Conway, MD[b]

Medicine (2022)
101:39

Table 2

Summary of metrics compared between pediatric survivors and non-survivors of ECPR.

Metric	Studies	Population	Survivors	Non-survivors	*I²*	*P*	Risk ratio [95% CI]	Hedge's g [95% CI]
Demographics								
Age	24	2610	343 ± 1045	440 ± 1372	72%	.66		0.04 [-0.14 - 0.21]
Gender-Male	18	2514	55%	59%	22%	.28	0.93 [0.82 - 1.06]	
Race-Asian	5	1408	11%	13%	0%	.43	0.73 [0.27 - 1.95]	
Race-Black	5	1286	15%	16%	31%	.78	1.05 [0.66 - 1.68]	
Race-Hispanic	4	1087	14%	15%	0%	.50	0.9 [0.68 - 1.21]	
Race-White	5	1286	61%	56%	14%	.54	1.05 [0.87 - 1.26]	
Weight	19	2380	6.3 ± 8.4	6.3 ± 9.8	74%	.18		0.12 [-0.06 - 0.3]
Pre-ECPR lab measurements								
Creatinine	4	193	0.83 ± 0.56	1.1 ± 0.7	21%	<.01		-0.41 [-0.7 - -0.12]
Bicarbonate	5	1328	19.8 ± 8.6	20 ± 9.4	18%	.68		0.03 [-0.18 - 0.25]
Lactate	11	616	6.9 ± 6.1	9.6 ± 7.6	41%	.02		-0.36 [-0.64 - -0.07]
$PaCO_2$	5	842	55.7 ± 25.0	60.2 ± 33.0	0%	.045		-0.13 [-0.26 - 0]
PaO_2	4	1061	44.1 ± 44.4	38.4 ± 37.5	8%	<.01		0.25 [0.13 - 0.38]
pH	15	2005	7.2 ± 0.2	7.1 ± 0.3	0%	<.01		0.21 [0.09 - 0.33]
Pre-ecpr co-morbidities								
Single ventricle physiology	12	1390	39%	45%	47%	.35	0.85 [0.58 - 1.23]	
Primary myocardial disease	12	1580	12%	7%	31%	.13	1.5 [0.87 - 2.6]	
Pulmonary hypertension	3	270	3%	5%	0%	.22	0.44 [0.12 - 1.61]	
Renal failure	3	129	24%	46%	0%	<.01	0.47 [0.28 - 0.81]	
Sepsis	3	1020	3%	6%	24%	.04	0.52 [0.28 - 0.97]	
Intra-ECPR characteristics								
CPR duration	17	1204	37.3 ± 25.2	47.9 ± 38.3	37%	.00		-0.36 [-0.54 - -0.18]
ECMO duration	21	2330	96.9 ± 120.3	118.9 ± 115.7	30%	.00		-0.23 [-0.36 - -0.1]
ECMO Flow Rate at 24 h	3	786	118.5 ± 49.2	130.8 ± 53.9	0%	.03		-0.15 [-0.3 - -0.01]
ECMO Flow Rate at 4 h	4	826	119.1 ± 51.1	124.3 ± 58.2	0%	.64		-0.03 [-0.17 - 0.11]
Site-femoral	2	143	11%	15%	0%	.43	0.71 [0.31 - 1.65]	
Site-neck	6	343	40%	43%	0%	.37	0.9 [0.68 - 1.19]	
Site-thorax	6	399	54%	54%	12%	.47	1.09 [0.82 - 1.45]	
Shockable rhythm	6	1205	17%	11%	0%	.01	1.51 [1.14 - 1.98]	
Neurological complications	9	2320	17%	37%	31%	<.01	0.43 [0.32 - 0.58]	
Post-ECPR complications								
Pulmonary hemorrhage	4	1076	2%	7%	49%	<.01	0.34 [0.17–0.69]	
Renal failure	4	540	22%	48%	0%	0	0.47 [0.36 - 0.61]	
Sepsis	4	243	15%	26%	0%	.033	0.57 [0.34 - 0.96]	

ECPR = extracorporeal cardiopulmonary resuscitation.

N=3794
30 Studien

CPR Dauer
Laktat, pH
Lungenblutung
Neurologische Komplikationen

Mortality Score

Prognostic Evaluation of Mortality after Pediatric Resuscitation Assisted by Extracorporeal Life Support
A.De Mul et all
J Pediatr Intensive Care 2019

Ziel: Prognose aus pre-eCPR Faktoren bestimmen

3 Zentren, 55 Patienten, retrospektiv, 2008-2016, IHCA, 2/3 kardial

Cutoff 9 predictive value 94%

Variable	**1Punkt**	**2Punkte**	**3Punkte**	**6Punkte**
CPR Dauer in Minuten	<40	40-59	60-104	>105
Laktat (mMol/L)	<8	8-13,9	14-17,9	>18
pH	>7,00	6,85-7,00	6,61-6,84	>6,6

AHA: CCF>80% – CC Pause <10sec

CCPR Qualität Outcome –bestimmend (Circulation 2015,Resuscitation 2019, Pediatr Crit Care Med 2020)

ECPR – 5min vor Kanülierung Outcome – bestimmend (Lauridsen KG et all Resuscitation 2022)

CPR-Pausen (Video) 22% > 10 s (O´Connell et all Resuscitation 2019)

CPR-Pausen vermeidbar (Jones et all Pediatr Crit Care Med 2020)

Keine Zeit für Pausen

Es ist Zeit für Monitoring

ECPR trifft auf CCPR Team

CCPR

Platz

Team (TL, TM AB,C2,D)

CPR Qualität

Checklisten

Koordinatoren (kein ROSC – ECPR Indikation)-Team (PICU/Kardiologe/Chirurgie)

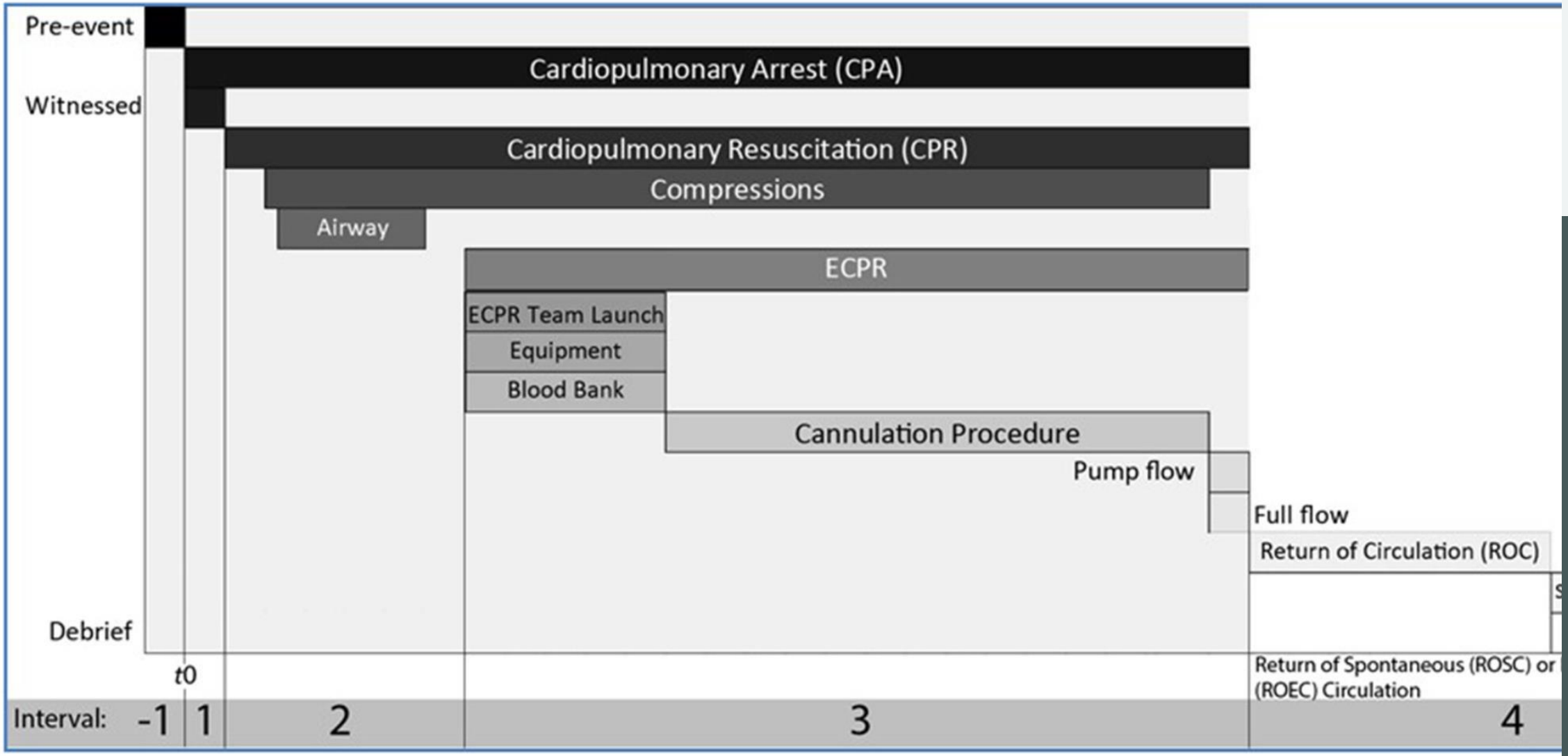
ECPR

Viel, viel Platz

Checklisten

Koordinatoren (Wer, Wo, Was wird implantiert)

Team (Chirurgie, OP-Team, Perfusionist, Anästhesie, PICU, Kardiologie)


Pre-event
Cardiopulmonary Arrest (CPA)
Witnessed
Cardiopulmonary Resuscitation (CPR)
Compressions
Airway
ECPR
ECPR Team Launch
Equipment
Blood Bank
Cannulation Procedure
Pump flow
Full flow
Return of Circulation (ROC)
Debrief
t0
Return of Spontaneous (ROSC) or
(ROEC) Circulation
Interval: -1 1 2 3 4

DIDACTICS

Eight didactic sessions covering neonatal, pediatric, and adult ECMO:

- Common indications
- Pathophysiology
- Candidacy
- Cannulation strategies
- Complications

WET LABS

Progressive increase in difficulty
Repeated and timed until proficient

- Construct full dry circuit
- Prime with crystalloid fluid and blood
- Pump, oxygenator, circuit change

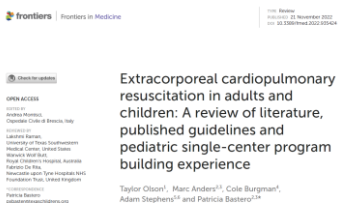
SIMULATION: TECHNICAL SKILLS

- Air entrapment
- Hypovolemia
- Pump failure
- Hand-cranking
- Oxygenator change
- Blood product administration
- Priming

SIMULATION: TEAM TRAINING

- Cannulation
- ECPR
- Circuit trouble shooting
- ECMO priming and initiation of support
- ECMO Transport

Active shadowing of ECMO provider and supervised patient care
Feedback and debriefing sessions


frontiers | Frontiers in Medicine

Extracorporeal cardiopulmonary resuscitation in adults and children: A review of literature, published guidelines and pediatric single-center program building experience

FIGURE 2
Texas children's hospital ECMO training program. ECMO, extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation.

	IHCA	**OHCA**
AHA	Cardiac: ECPR soll überlegt werden: ECMO Protokoll, Expertise und Equipment Non-Cardiac: insuffiziente Daten	Insuffiziente Daten
ERC	IHCA oder ED empfiehlt ECPR zu überlegen wenn eine reversible Grunderkrankung besteht und das Setting zur Verfügung steht	Wenn Zeitfaktor und Qualität der CCPR adequat kann überlegt werden; strenge Indikationsstellung Ausnahme:Hypothermie OH-Kanülierung durch Experten; no bzw low-flow Time bekannt, reversible Ursache Geld spielt keine Rolle
ILCOR	Zu überlegen bei streng selektionierten Säuglingen und Kindern und entsprechendem Team (weak recommendation, very low-quality evidence)	Insuffiziente Daten
ELSO	Institutionen mit Protokoll und high quality CCPR und ECPR, Senior entscheidet; CA beobachtet und reversible Ursache	Insuffiziente Daten für Empfehlung Gilt auch für Trauma, Lawinen – oder Ertrinkungsopfer bzw. CPR - Transport

eCPR PICU Protokoll

CA an PICU,HK,Kinderklinik

ECMO-Einsatz individuell I cong od erworbene Herzfehler, II nicht-kardiale Grunderkrankung, III laufende CPR von Rettung (A cardial B nicht-cardial)

Voraussetzung: effiziente,laufende CPR

Indikationsstellung durch PICU-OA innerhalb 15 Min in Absprache mit I Herzchirurgen+Kardiologe, II Herzchiurgen+Fach-OA, III

Kontraindikation: generell für ECMO

Praktisches Vorgehen: Guidelinekonforme CPR , Aktivierung Kardiodienst- Information Chef der kardiologie, NEO-Dienst hinzuziehen, ECMO-Kanülierung 24h durch Kinder-Herzchirurgie+PICU Chef Information, ECMO-System <15kg auf PICU,>15kg von Kardiotechnik, Priming vorbereiten + Blutprodukte organisieren

SCORE

OHCA/IHCA – Fall 1

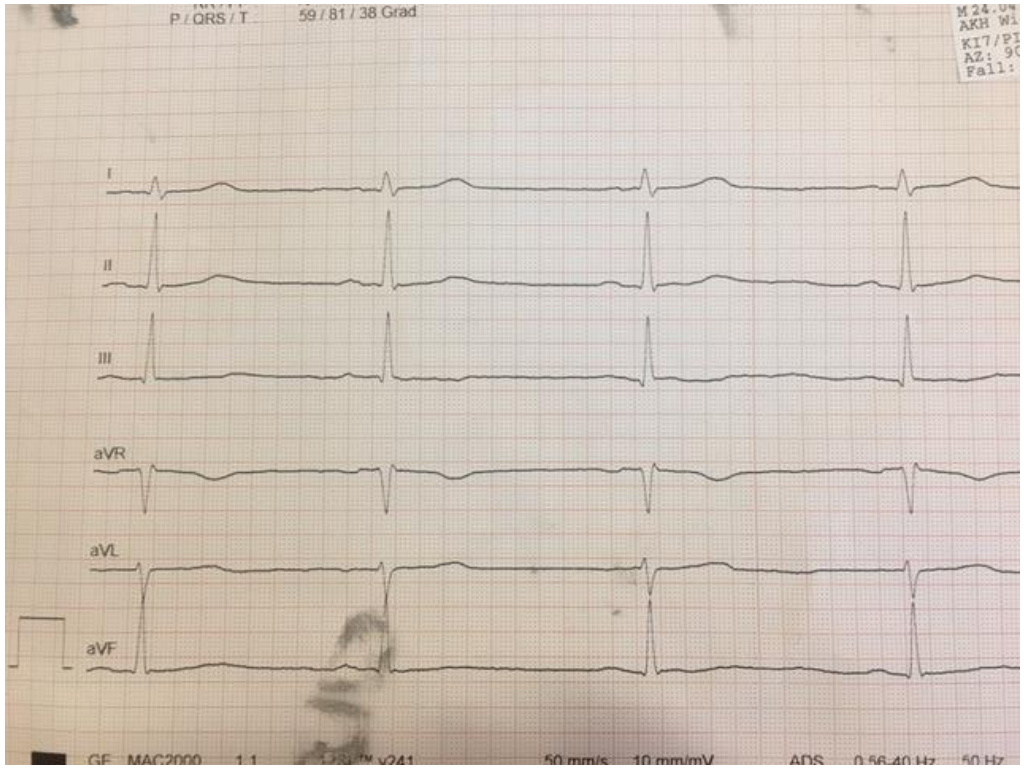
Non-Responder auf Therapie

Laktatanstieg bis 12,9

VA- ECMO

Hämodynamische Stabilisierung

- Blutdruck altersentsprechend
- Perfusion
- Harnproduktion
- Laktatnormalisierung



OHCA/IHCA – Fall 1

OHCA – Fall 2

VA-ECMO-Beginn nach 30 min.

Sinusrhythmus bei 29°

Temperaturkontrolle auf 33°

Kreislauf und Normalisierung der Laborwerte innerhalb 24h

Entwöhnung nach 48h

KONKLUSIO

eCPR zum Erreichen eines ROSC ist machhbar

Bestes Survival bei Kardialen Ursache v.a. p-OP

Nicht-Kardiale Ursachen potentiell möglich

Qualität cCPR ist Voraussetzung

Plan (Indikationsstellung, Ablauf, Ausbildung)

Zahlen, Daten, Fakten insuffizient (Indikation, Outcome, Kosten)

Outcome ECMO/HLM

A.S.	ARDS/CA	spastische Tetraparese	ECMO	6
F.Z	ARDS	gesund	ECMO	5
K.S	Hypothermie	Tod	HLM	6
K.D	ARDS	gesund	ECMO	5
M.Th	Hypothermie	Veget. State	HLM	6
P.B.	Hypothermie	Hirntod	ECMO	6
P.A.	Hypothermie	Hirntod	ECMO	6
P.M	Hypothermie	Durchgangssyndrom	ECMO	6
W.L	Hypothermie	Tod	ECMO	6
W.P	Hypothermie	Bewegungsstörung	HLM	6
K.M.	Hypothermie	gesund	HLM	5
K.N.	ARDS	gesund	ECMO	5
B.Ch	Hypothermie	Tetraparese	ECMO	6
R.R.	Hypothermie	Hirntod	ECMO	6
W.R.	Hypothermie	Hirntod	ECMO	6

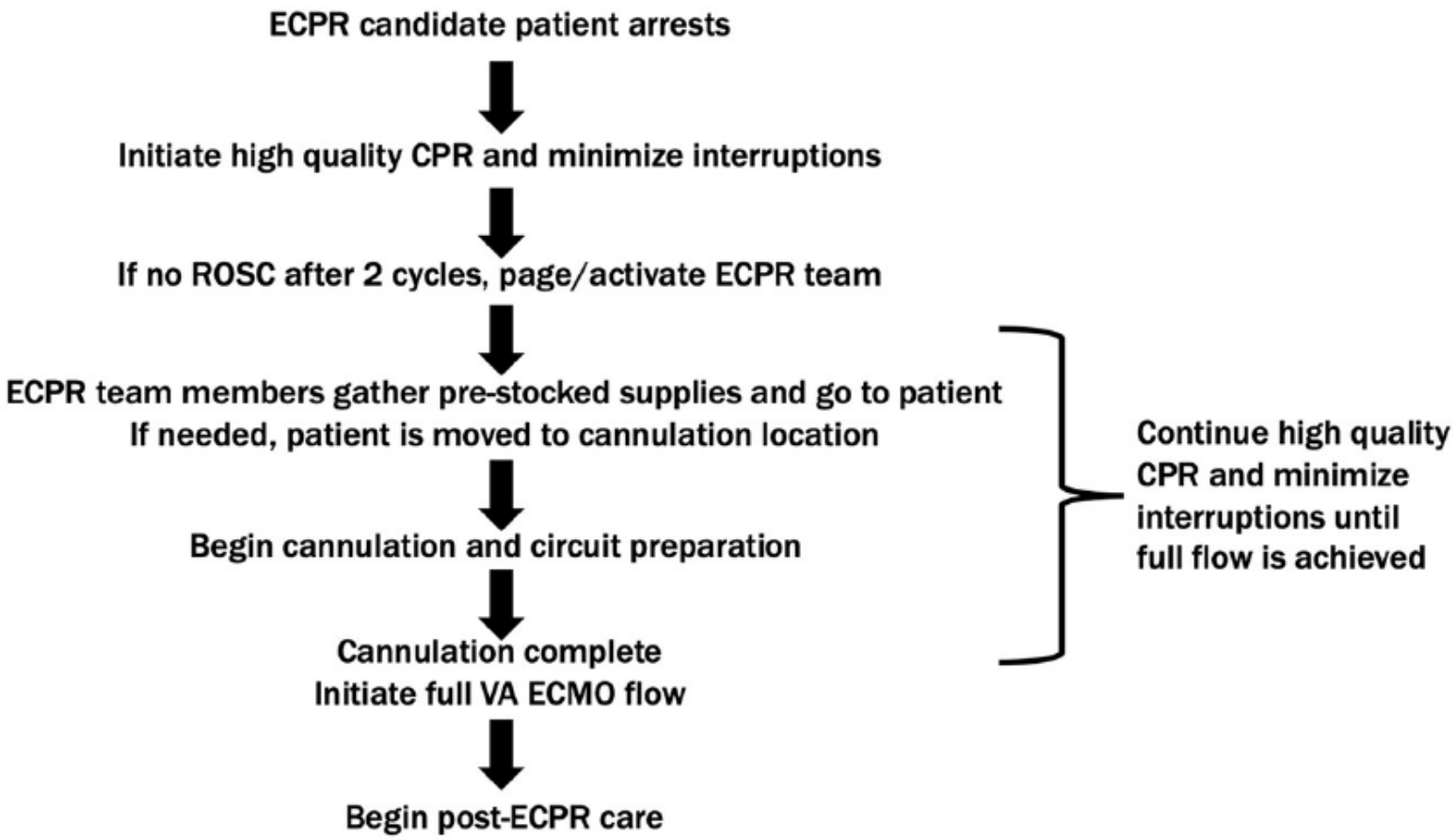


FIGURE 1
ECPR deployment algorithm. ECPR, extracorporeal cardiopulmonary resuscitation; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; VA ECMO, veno-arterial extracorporeal membrane oxygenation.