2025 ILCOR Statement

2025 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations

Pediatric Life Support

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ABSTRACT

The International Liaison Committee on Resuscitation conducts continuous review of new peer-reviewed published cardiopulmonary resuscitation science and publishes annual summaries. More comprehensive reviews are published every 5 years. The Pediatric Life Support Task Force chapter of the 2025 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations addresses all published resuscitation evidence reviewed by International Liaison Committee on Resuscitation Pediatric Life Support Task Force members in the past year, as well as brief summaries of topics reviewed since 2020, to provide a more comprehensive update. In total, 39 questions related to pre-arrest, intra-arrest, and post-arrest resuscitation phases of pediatric cardiac arrest are included, including systematic reviews, scoping reviews, and evidence updates. Members of the task force assessed, discussed, and debated the quality of evidence, based on Grading of Recommendations, Assessment, Development, and Evaluation criteria, and their statements include consensus treatment recommendations. Insights into deliberations of the task force are provided in the *Justification and Evidence-to-Decision Framework Highlights* sections. The task force has also listed priority knowledge gaps for further research.

INTRODUCTION

The International Liaison Committee on Resuscitation (ILCOR) Pediatric Life Support (PLS) Task Force section of the *2025 International Consensus on Cardiopulmonary Resuscitation* (CPR) *and Emergency Cardiovascular Care Science With Treatment Recommendations* (CoSTR) includes all reviews conducted by the PLS Task Force in the past year. Reviews conducted and published since the 2020 CoSTR are also summarized to provide a single comprehensive reference document for readers. The PLS Task Force work encompasses 39 reviewed PICOST (population, intervention, comparator, outcome, study design, and time frame) reports, including 22 systematic reviews (SysRev). Draft CoSTRs for all topics evaluated with a SysRev in the past year were posted on a rolling basis on the ILCOR website.[1] Each draft CoSTR included the data reviewed and draft treatment recommendations, with public comments accepted for 2 weeks after posting. The task force considered public feedback and provided responses. All CoSTRs are available online.[1]

Although only SysRevs can generate a full CoSTR and new treatment recommendations, many other topics were evaluated with scoping reviews (ScopRevs) or evidence updates (EvUps). Good practice statements, which represent the opinion of task force experts in light of very limited or no direct evidence, can be generated after ScopRevs and occasionally after EvUps in cases where the task force thinks providing guidance is especially important. A separate publication in this issue includes the full details of the evidence evaluation process.[2]

This statement contains the final wording of the treatment recommendations and good practice statements as approved by the ILCOR PLS Task Force, as well as summaries of the key evidence identified, key discussion points, and knowledge gaps. Links to the published reviews and full online CoSTRs are provided in the corresponding sections. Evidence-to-decision tables for SysRevs are provided in Appendix A, and the complete EvUp worksheets are provided in Appendix B.

Topics are presented using the PICOST format. Where appropriate, the population, context, and concept framework was used.[3] Search strategies were kept deliberately broad to capture all clinical outcomes. The task force then graded available outcomes into critical or important with a preference for outcomes defined in the Pediatric Core Outcome Set for Cardiac Arrest (P-COSCA).[4] To minimize redundancy, the study designs have been removed from the text except in cases where designs included differed from the PLS standard criteria. Randomized controlled trials (RCTs) and nonrandomized studies (nonrandomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Case series were included if they contained ≥5 cases. Unpublished studies (eg, conference abstracts, trial protocols), animal studies, mathematical models, simulation and manikin studies, and algorithm studies with no outcome data were excluded. All languages were included, provided there was an English abstract. The following topics are addressed in this 2025 PLS Task Force CoSTR:

Periarrest

- Bradycardia with hemodynamic compromise in children (PLS 4030.30, ScopRev 2025)
- Resuscitation of durable mechanical circulatory supported patients with acutely altered perfusion or cardiac arrest (PLS 4190.03, ScopRev 2025)
- Pediatric early warning systems (PLS 4050.02, SysRev 2022)
- Management of pulmonary hypertension (PLS 4160.11, ScopRev 2024, EvUp 2025)

Intra-arrest: Airway, Breathing, Circulation

- Airway, breathing, and circulation (ABC) versus compressions, airway, breathing (CAB): order of ventilation and compression (PLS 4070.02, SysRev 2025)
- Advanced airway interventions in cardiac arrest (PLS 4060.01, SysRev 2024, EvUp 2025)
- Ventilation rate with advanced airway during cardiac arrest (PLS 4120.02, SysRev 2024, EvUp 2025)

Intra-arrest: Defibrillation

- Energy doses for pediatric defibrillation during resuscitation (PLS 4080.12, SysRev 2025)
- Paddle/pad size and placement in infants and children (PLS 4080.17, SysRev 2025)
- Single or stacked shocks for pediatric defibrillation (PLS 4080.19, SysRev 2025)
- Lay rescuer use of automated external defibrillators (AEDs) (PLS 4080.01, SysRev 2022, EvUp 2025)

Intra-arrest: Monitoring

- Pulse check accuracy in pediatrics during resuscitation (PLS 4080.18, SysRev 2025)
- Blood pressure monitoring and targets during pediatric in-hospital cardiac arrest (PLS 4160.08, SysRev 2025)
- Intra-arrest echocardiography (point-of-care cardiac ultrasound) (PLS 4160.05, ScopRev 2020, EvUp 2025)
- Intra-arrest end-tidal CO_2 (PLS 4160.07, ScopRev 2020, EvUp 2025)
- Intra-arrest near-infrared spectroscopy (PLS 4160.09, ScopRev 2020, EvUp 2025)

Intra-arrest: Drugs and Drug Administration

- Vasopressor use during cardiac arrest in children (PLS 4080.21, SysRev 2025)
- Epinephrine administration timing in cardiac arrest (PLS 4090.02, SysRev 2020, EvUp 2025)
- Calcium use during cardiac arrest (PLS 4090.01, SysRev 2023, EvUp 2025)
- Sodium bicarbonate administration in cardiac arrest (PLS 4090.04, EvUp 2020, EvUp 2025)
- Anti-arrhythmic drugs in cardiac arrest with shockable rhythms (PLS 4080.04, SysRev 2018, EvUp 2025)
- Intraosseous (IO) versus intravenous (IV) in cardiac arrest (PLS 4080.15, SysRev 2020, EvUp 2025)

Intra-arrest: Special Circumstances

- Cardiopulmonary resuscitation in obese patients (PLS 4080.22, ScopRev 2025)
- In-hospital cardiac arrest (IHCA) due to suspected cardiac shunt/stent obstruction (PLS 4030.25, SysRev 2025)
- Cardiac arrest due to pulmonary embolism (PLS 4160.10, SysRev 2025)
- Pharmacological interventions for the treatment of hyperkalemia in children with cardiac arrest (PLS 4160.17, SysRev 2025)

Intra-arrest: Extracorporeal Cardiopulmonary Resuscitation

- Extracorporeal cardiopulmonary resuscitation (ECPR) in pediatric cardiac patients with single ventricle physiology (PLS 4030.09, 4030.10, SysRev 2025)
- ECPR for cardiac arrest (PLS 4160.02, SysRev 2023, EvUp 2025)

Postresuscitation

- Post–return of spontaneous circulation (ROSC) blood pressure targets (PLS 4190.01, SysRev 2025)
- Prediction of survival with poor neurological outcome after return of circulation following pediatric cardiac arrest, combined prognostic SysRev:
  - Blood biomarkers (PLS 4220.01, SysRev 2025)
  - Clinical examination (PLS 4220.02, SysRev 2025)
  - Electrophysiology testing (PLS 4220.03, SysRev 2025)
  - Brain imaging (PLS 4220.04, SysRev 2025)
- Prediction of survival with good neurological outcome after return of circulation following pediatric cardiac arrest - combined prognostic SysRev:
  - Blood biomarkers (PLS 4220.05, SysRev 2023)

  - Clinical examination (PLS 4220.06, SysRev 2023)
  - Electrophysiology testing (PLS 4220.07, SysRev 2023)
  - Brain imaging (PLS 4220.08, SysRev 2023)
- Effect of prophylactic antiseizure medication and/or treatment of seizures on outcome of pediatric patients following cardiac arrest (PLS 4210.02, SysRev 2024**)**
- Post-ROSC oxygenation and ventilation (PLS 4180.01, 4180.02, SysRev 2019, EvUp 2025)

Readers are encouraged to monitor the ILCOR website[5] to provide feedback on planned systematic reviews and to provide comments when additional draft reviews are posted.

PERIARREST

Bradycardia With Hemodynamic Compromise in Children (PLS 4030.30, ScopRev 2025)

Rationale for Review

Bradycardia (heart rate <60 beats per minute) may result from intrinsic heart issues or external factors such as hypoxemia and metabolic disorders. Bradycardia can lead to hemodynamic compromise, cardiopulmonary failure, and potentially pulseless cardiac arrest. Current resuscitation guidelines recommend epinephrine for persistent bradycardia with poor perfusion during CPR[6]; however, there are few data on the natural progression of bradycardia during CPR and the efficacy of epinephrine or other drugs.[7] The ILCOR PLS Task Force prioritized a ScopRev of this topic because of the high prevalence of this presentation in children. The full ScopRev report can be found on the ILCOR website.[8]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Children with bradycardia (heart rate of <60 or heart rate low for age) with hemodynamic compromise in hospital or out-of-hospital setting
- Intervention: Any specific management strategies including but not limited to oxygenation or ventilation, anticholinergic drugs (eg, atropine), inotropes or chronotropes (eg, epinephrine, isoproterenol), electrophysiologic pacing (eg, transcutaneous pacing, temporary cardiac pacing) or CPR
- Comparators: Another specific management strategy including another drug, therapy, placebo, or no drug
- Outcomes: Any clinical outcome
- Time frame: All years to October 6, 2025.

Summary of Evidence

Of the initial 4851 studies identified, 23 were included,[7,9-30] of which 19 described the prevalence and outcomes in children who had cardiac arrest with an initial documented rhythm of bradycardia with poor perfusion and thus did not directly address this PICO question.[11-29] Two papers commented on the impact of atropine for bradycardia with hemodynamic compromise, 1 in patients receiving CPR and 1 in patients who never received CPR.[9,30] Three papers studied the administration of epinephrine during CPR for first documented rhythm of bradycardia with poor perfusion.[7,9,10] Studies on atropine and epinephrine are summarized in Table 1. No studies were identified that assessed administration of oxygen, ventilation, or transcutaneous pacing.

Table 1. Studies Reporting Treatment and Outcomes for Bradycardia with Hemodynamic Compromise

Author, year	Country, design, age	Population	Treatment/ exposure	Patients analyzed, (N events)	Total patients with bradycardia and poor perfusion	Outcomes (%)
Atabek, 2002[30]	Turkey, Case series, 2-5 yr olds	Amitraz poisoning	Atropine (given 6-10 doses)	14	8	Survival to hospital discharge: 100% with resolution of bradycardia in all patients
Khera, 2019[9]	United States, Multicenter retrospective cohort, >30 days and < 18 years	CA	CPR	2799 bradycardia initial rhythm with poor perfusion receiving CPR (50% of 5592 total CA cohort)	1930 (69%) maintained pulse 869 (31%) with subsequent pulselessness.	Survival to hospital discharge (unadjusted) 70% in those who maintained a pulse versus 30.2% in those with subsequent pulselessness ($p < 0.01$) Survival to hospital discharge (adjusted)57% lower risk of survival with subsequent pulselessness compared with maintained pulse ($p<0.01$) RR 0.43; 95% CI: 0.38, 0.50; $P<0.001$
			CPR and atropine	854/2799 (30.5%)	519/1930 (26.9%) maintained pulse 335/869 (38.6%) subsequent pulselessness	No survival to hospital discharge with CPR and atropine

Author, year	Country, design, age	Population	Treatment/ exposure	Patients analyzed, (N events)	Total patients with bradycardia and poor perfusion	Outcomes (%)
			CPR and epinephrine	1967/2799 (70.3%)	1153/1930 (65.5%) maintained plus (814/869 (95.2%) subsequent pulselessness	No survival to hospital discharge with CPR and epinephrine
Holmberg, 2020[7]	United States, Multicenter retrospective cohort propensity matched, ≤18 years	CA-bradycardia with poor perfusion	CPR and epinephrine (given within 10mins of CPR) versus CPR and no epinephrine	7056	7056	Survival to hospital discharge with CPR and epinephrine 38% versus no epinephrine 48% RR 0.79 [95% CI 0.74, 0.85] p<0.001) Survival to 24 hours: lower for CPR and epinephrine 0.85 (0.81, 0.90) ROSC lower with CPR and epinephrine 0.94 (0.91, 0.96) Favorable neurological outcome at discharge lower with CPR and epinephrine 0.76 (0.68, 0.84)
O'Halloran, 2023[10]	United States, Multicenter retrospective cohort, <19 yrs	CA - bradycardia	Early "bolus" (epi within first 2 min of CPR) versus no early bolus (no bolus epi or epi >2 min after CPR) 322/452 (71%) CPR and early epi CPR	452 Subanalysis: 186 with invasive ABP assessed during first 10 min CPR 179 received epinephrine and CPR	452 Classified as 68 never pulseless, 53 pulseless and returned to pulse, 65 became pulseless and remained pulseless*	Favorable neurologic outcome at hospital discharge with early epinephrine administration 51% versus 58% (RR 0.99 [95% CI 0.82, 1.18]; p=0.89) ROSC: 57/68 (84%) never became pulseless 33/53 (62%) became pulseless and then developed bradycardia with a pulse again 28/65 (43%) developed pulselessness and stayed pulseless (p=0.001) ROSC (85%) among those patients who never developed pulselessness and received early epinephrine (p < 0.001)

*On arterial line wave form was described as no pulse or SBP <40 mm Hg for infants (<1 year of age) and <50 mm Hg for children ≥1 year of age

ABP indicates ; CA, cardiac arrest; CI, confidence interval; CPR, cardiopulmonary resuscitation; ROSC, return of spontaneous circulation; RR, risk rati0

Task Force Insights

The task force identified numerous gaps in the literature, including absence of studies evaluating bradycardia with hemodynamic compromise in patients not receiving CPR and lack of comparison groups for interventions (eg, CPR versus no CPR) for bradycardia with hemodynamic compromise.

All studies evaluating CPR for bradycardia with hemodynamic compromise were in patients who were already receiving CPR for presumed cardiac arrest. The task force discussed timing of initiation of CPR for bradycardia for hemodynamic compromise, specifically as most studies were retrospective, and thus the true reason for CPR initiation is unknown.

The task force considered indirect evidence supporting CPR for bradycardia with hemodynamic compromise, specifically studies that show (1) patients receiving CPR for bradycardia with hemodynamic compromise have better survival rates than those receiving CPR for asystole or pulseless electrical activity, and (2) patients receiving CPR for bradycardia with hemodynamic compromise who maintained that rhythm had higher survival rates than those who progressed to pulselessness. There was concern about potential harm associated with delaying initiation of CPR for patients with bradycardia and hemodynamic compromise who are not responsive to oxygenation and ventilation as progression to pulselessness is associated with worse outcomes.

There was insufficient data to support a good practice statement for atropine, epinephrine, or transcutaneous pacing. The scoping review did not identify a sufficient evidence base to support a SysRev.

Treatment Recommendations (2025)

For patients with bradycardia and hemodynamic compromise not responsive to oxygenation and ventilation, consider initiating CPR (good practice statement).

Withdrawn Treatment Recommendations

Based on the lack of any available direct or indirect evidence considered appropriate by the task force for inference, these previous treatment recommendations are all withdrawn.

Epinephrine may be administered to infants and children with bradycardia and poor perfusion that is unresponsive to ventilation and oxygenation (2010, withdrawn 2025).

It is reasonable to administer atropine for bradycardia caused by increased vagal tone or anti-cholinergic drug toxicity. There is insufficient evidence to support or refute the routine use of atropine for pediatric cardiac arrest (2010, withdrawn 2025).

In selected cases of bradycardia caused by complete heart block or abnormal function of the sinus node, emergency transthoracic pacing may be lifesaving. Pacing is not helpful in children with bradycardia secondary to a post-arrest hypoxic/ischemic myocardial insult or respiratory failure. Pacing was not shown to be effective in the treatment of asystole in children (2000, withdrawn 2025).

Resuscitation of Patients Living With Durable Mechanical Circulatory Support With Acutely Altered Perfusion or Cardiac Arrest (PLS 4190.03, ScopRev 2025)

Rationale for Review

This topic was chosen for review because of the increasing prevalence of durable mechanical circulatory supported devices, particularly left ventricular assist devices (LVADs). The optimal approach to identification and resuscitation of patients with acutely impaired perfusion supported by durable mechanical circulatory supported is controversial. The ScopRev was initiated as a nodal review with the Advanced Life Support (ALS) and PLS Task Forces.[31] The full ScopRev report can be found on the ILCOR website.[32]

Population, Concept, Context , Study Design, and Time Frame

- Population: Patients of any age receiving durable mechanical circulatory supported of any kind
- Concept: Acute impaired perfusion resulting in need for acute resuscitation

- Context: In- and out-of-hospital settings
- Study designs: In addition to standard criteria, all case series and reports were included.
- Time frame: Literature search included all years up to May 2024.

Summary of Evidence

Of the 32 studies included,[33-66] 24 were case reports including 2 or fewer patients,[33,36-40,42,45-53,55-58,62-66] 4 were case series including 3 to 10 patients,[34,41,44,60] and 3 were retrospective cohort studies including more than 10 patients.[35,43,59] Thirteen studies described patients who had cardiac arrest and received chest compressions.[34,38,39,41,47,50,51,55,56,58-60,65] In all studies, the durable mechanical circulatory supported was a left ventricular or biventricular assist device.

Task Force Insights

The task force identified few data to support recommendations on the optimal approach to resuscitation of mechanical circulatory supported patients who experience acutely impaired perfusion. Most publications identified were case reports or case series. The few observational cohort studies had limitations including confounding by indication, lack of generalizability, and a high risk of misclassification whereby patients with acutely impaired perfusion are designated as having a cardiac arrest but may not have had a cardiac arrest. No high-quality observational studies or randomized controlled trials were identified.

The task force noted the low risk of device dislodgement from chest compressions identified in the ScopRev. While several observational studies did find a higher risk of poor outcome when chest compressions were administered to patients with acutely impaired perfusion as a result of cardiac arrest compared with no chest compressions, these observational studies were judged to be at high risk for confounding.

The task force also reviewed a scientific statement from the American Heart Association and guidance from the British Societies LVAD Emergency Algorithm Working Group.[67,68] One area of

discussion was around the British Societies' recommendation to delay chest compressions in LVAD supported patients for up to 2 minutes while efforts to restart the device are made. The task force felt that these 2 minutes may be unnecessary, and efforts to restart the LVAD device could occur in parallel with chest compressions if multiple rescuers are available.

The ScopRev did not identify sufficient evidence to support a systematic review. The good practice statements generated are the same as those generated by the ALS Task Force.

Treatment Recommendations (2025)

In patients receiving durable mechanical circulatory support who develop acutely impaired perfusion because of cardiac arrest and who are not in the immediate peri-device implantation period, we suggest performing rather than withholding chest compressions (good practice statement).

When caring for patients with durable mechanical circulatory support who suffer acutely impaired perfusion as a result of cardiac arrest, we suggest minimizing delays in initiating chest compressions while simultaneously assessing for device-related reversible causes of acutely impaired perfusion (good practice statement).

We suggest rescuers follow an algorithmic approach to concurrently assess and respond to acutely impaired perfusion in patients receiving durable mechanical circulatory support (good practice statement).

Pediatric Early Warning Systems (PLS 4050.02, SysRev 2022)

The utility of pediatric early warning systems was addressed in a SysRev in 2022[69] and details can be found in the 2022 CoSTR summary.[70-72]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants, children, and adolescents in any inpatient setting
- Intervention: Pediatric early warning system with or without rapid response teams or medical emergency teams

- Comparators: No pediatric early warning system or standard care (without a scoring system)
- Outcomes:
  - Critical: significant clinical deterioration event, including but not limited to unplanned/crash tracheal intubation; unanticipated fluid resuscitation and inotropic/vasopressor use; CPR or extracorporeal membrane oxygenation; death in patients without a do-not-attempt resuscitation order.
  - Important: unplanned code events with favorable neurological outcome.
- Time frame: All years to June 26, 2021

Treatment Recommendations (2022)

We suggest using pediatric early warning systems to monitor hospitalized children, with the aim of identifying those who may be deteriorating (weak recommendation, low-certainty evidence).

Management of Pulmonary Hypertension (PLS 4160.11, ScopRev 2024, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children with pulmonary hypertension at high risk of pulmonary hypertensive crises with a cardiac arrest in the in-hospital setting including post-operatively.
- Intervention: Specific management strategies, including respiratory management and monitoring to avoid hypoxia and acidosis; use of opioids, sedatives and neuromuscular blocking agents; or pulmonary arterial hypertension-specific targeted therapy
- Comparators: Standard care without specific strategies for pulmonary hypertensive crisis
- Outcomes: Any clinical outcome
- Time frame: December 1, 2023, to October 17, 2024

Summary of Evidence

The complete EvUp is provided in Appendix B. There is no new published evidence since the ILCOR 2024 ScopRev on this topic, so a SysRev is not warranted.[73,74]

Good Practice Statements (2024)

In children, including neonates, with pulmonary hypertension hospitalized for a clinical worsening event, we propose avoiding factors that may increase pulmonary vascular resistance while treating the aggravating condition to decrease the risk of cardiac arrest. Management strategies include avoiding hypoxia; hypercapnia; acidosis; stressors, such as pain, agitation, dehydration, or fluid overload; anemia; infection; or arrhythmias. Pulmonary hypertension-specific treatments (eg, inhaled nitric oxide, L-arginine, phosphodiesterase inhibitors [eg, milrinone, sildenafil], or endothelin-1 inhibitors [eg, bosentan]) may be considered (good practice statement).[73,74]

In children who develop signs of pulmonary hypertensive crisis, low cardiac output, or right ventricular failure despite optimal medical therapy, extracorporeal membrane oxygenation (ECMO) may be considered before cardiac arrest or for refractory cardiac arrest (ie, ECPR) as a bridge to recovery or as a bridge to the evaluation for organ replacement and transplantation in very select cases (good practice statement).[73,74]

INTRA-ARREST: AIRWAY, BREATHING, AND CIRCULATION

ABC Versus CAB: Order of Ventilation and Compression (PLS 4070.02, SysRev 2025)

Rationale for Review

Because the merits of commencing chest compressions before ventilations are uncertain, we updated the previous SysRev, which was included in the 2019 CoSTR summary.[75,76] Previous SysRevs by ILCOR have found that in simulation studies starting CPR with compressions resulted in faster times to key elements of resuscitation (rescue breaths, chest compressions, completion of first

CPR cycle).[77,78] A change from ABC to compression-first and compression-focused CPR has also been associated with a significant increase in rates of bystander CPR and patient survival.[79] Most international adult basic life support (BLS) guidelines now commence CPR with chest compressions before ventilations. Pediatric guidelines vary, with different approaches in various jurisdictions.[80] The SysRev was registered before initiation (Prospective Register of Systematic Reviews [PROSPERO] Registration CRD42024583890) and conducted as a nodal review with the BLS Task Force. The full CoSTR can be found on the ILCOR website.[81]

Population, Intervention, Comparator, Outcome, Study Design, and Time Frame

- Population: Adults and children in any setting (in-hospital or out-of-hospital) with cardiac arrest
- Intervention: Commencing CPR with compressions first (30:2)
- Comparators: Commencing CPR with ventilations first (2:30)
- Outcomes:
  - Critical: Survival with favorable neurological outcome at hospital discharge or 30-days; survival at hospital discharge or 30 days; survival with favorable neurological outcome to 1 year; survival to 1 year; event survival; any ROSC.
  - Important: Time to commencement of rescue breaths; time to commencement of first compression; time to completion of first CPR cycle; ventilation rate; compression rate; chest compression fraction; minute ventilation.
- Study designs: In addition to standard criteria, simulation studies were included if there were insufficient human studies.
- Time frame: September 2019 to June 18, 2024.

Consensus on Science

This updated systematic review identified 1 new pediatric manikin study[82] (published with corrections[83]), in addition to 4 manikin studies[84-87] found in the previous ILCOR reviews.[77,78,88,89] Of the 5 manikin studies, 3 were randomized studies, 1 in adult[85] and 2 in pediatric resuscitation,[82,87] and 2 were observational studies in adult resuscitation.[84,86] No human studies were identified.

The overall certainty of evidence was rated as very low for all outcomes, downgraded for very serious risk of bias and indirectness.

A summary of the outcomes of the included studies is shown in Table 2.

Table 2. Summative Results of Studies for CAB versus ABC Systematic Review

Outcomes (Importance)	Participants (Studies), n	Certainty of Evidence (GRADE)	CAB v ABC	P value
Time to commencement of chest compressions (important)	159 2-person teams (1 cross-over pediatric manikin randomized study)[87]	Very low	Mean: 19.3 ±2.6s versus. 43.4 ±5.0s	p<0.05
	108 2-person teams (1 adult manikin randomized study)[85]	Very low	Mean: 25 ±9 seconds versus. 43 ±16s	p<0.001
	33 6-person teams and 40 single rescuers (2 adult manikin observational studies)[84,86]	Very low	Median: 16.0s (IQR: 14.0-26.0) versus. 42.0 (IQR: 41.5-59.0) [84] Mean: 15.4 ±3.0s versus. 36.0 ±4.1s [86]	p<0.001 p<0.001
Time to commencement of ventilations (important)	267 2-person teams (2 randomized manikin studies) [85,87]	Very low	Mean: 28.4 ±3.1s versus. 22.7 ±3.1s [87] 43 ±10s versus. 37 ±15s [85]	p < 0.05 p<0.001
Time to completion of first CPR cycle (30 chest compressions + 2 breaths) (important)	108 2-person teams (1 randomized manikin study) [85]	Very low	Mean: 48 ±10s versus. 63 ±17s	p<0.001
Ventilation rate (important)	28 2-person teams (1 cross-over pediatric randomized manikin study) [82]	Very low	Median ventilations in first minute: 10 (IQR: 8-10) versus. 13 (IQR: 12-15)	p<0.05
Compression rate (important) **Compression rate (important)**	28 2-person teams (1 cross-over pediatric randomized manikin study) [82]	Very low	No difference	
	33 6-person teams (1 adult observational study) [84]	Very low	No difference	
Chest compression fraction (important) **Chest compression fraction (important)**	28 2-person teams (1 cross-over pediatric randomized manikin study) [82]	Very low	66% (IQR: 59-680 versus. 57% (IQR: 54-64)	p<0.001
	33 6-person teams (1 adult observational study) [84]	Very low	No difference	
Minute alveolar ventilation in first minute (important)	28 2-person teams (1 cross-over pediatric randomized manikin study) [82]	Very low	Median: 276mL (IQR:140–360 versus. 370mL (IQR: 203-472)	p<0.001

ABC indicates airway, breathing, circulation; CAB, compressions, airway, breathing; and GRADE, Grading of Recommendations, Assessment, Development, and Evaluation.

Treatment Recommendation (2025)

There is insufficient evidence to support a treatment recommendation regarding the optimal order of commencing CPR in children (ie, ventilation or compressions first).

The task force considers that both an ABC (ventilation followed by compression) and a CAB (compression followed by ventilation) approach are acceptable and that both ventilation and chest compressions are important components of CPR in children (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

The majority of the existing evidence (5 manikin studies) [82,84-87] suggests that starting CPR with compressions results in faster times to key elements of resuscitation.

One simulated study in pediatric resuscitation found that starting with compressions delayed the commencement of rescue breaths in cardiac arrest by 6 seconds.[87] This delay may be clinically acceptable. However, alveolar minute ventilation and the number of ventilations delivered in the first minute of resuscitation were higher with the ABC (delivering 5 rescue breaths before commencing chest compressions) sequence.

Indirect evidence from before-and-after out-of-hospital cardiac arrest (OHCA) registry studies in adults, examining changes in dispatcher telephone CPR instructions[79] and implementation of guideline changes,[90,91] suggests that switching from the ABC to CAB approach was associated with increased rates of bystander CPR[79] and improved patient outcomes.[79,90,91] Similar data on in-hospital cardiac arrest show conflicting evidence in patient outcomes.[92,93] One large registry study from Japan demonstrated increased bystander CPR rates in children with bystander-witnessed OHCA after compression-only CPR was introduced.[94] Whether the change in sequence to CAB by some ILCOR member councils has resulted in more infants and children receiving compression-only CPR overall is

unknown, although available data continues to support the combination of compressions and breaths is needed for optimal pediatric CPR.[95,96]

The BLS and PLS Task Forces also considered

- The benefits of a single training approach versus separate approaches for adults and children, recognizing regions currently using an ABC approach in children may incur additional short-term costs and resources to implement a CAB approach
- Effective chest compressions generate cumulative coronary perfusion pressure, which falls to near zero when compressions stop[97]
- Time to first compression is associated with better patient outcomes, including good neurological outcomes in adults.[98]
- Bystanders are typically unable to deliver effective ventilations during simulated CPR.[99]
- Due to the public's concerns with mouth-to-mouth ventilations,[100] commencing CPR with airway and ventilations may result in no bystander CPR being provided
- Delivering the ABC approach leads to more errors in CPR;[87] lay bystanders prefer CAB, and it is easier to learn and retain[87]
- The delivery of non-mouth-to-mouth ventilation requires the retrieval and preparation of equipment (eg, bag-valve-mask, pocket mask), which, when multiple rescuers are present, can occur during chest compressions.
- The new treatment recommendation in children is about starting CPR and does not mean ventilation should not be provided in resuscitation.
- While the PLS Task Force appreciates that most cardiac arrests in infants and children have a respiratory etiology, the short delay in starting ventilation is unlikely to make a clinically significant difference to outcome.

- Further investigation is needed in children. The task forces noted that Utstein-based registry data may be the only source of information to answer this question. Because different councils worldwide have adopted CAB versus ABC, comparative studies of different registries may provide evidence to answer this question.

Knowledge Gaps

No human studies directly evaluating this question in any setting were identified.

Advanced Airway Interventions in Cardiac Arrest (PLS 4060.01, SysRev 2024, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) who had received CPR after out-of-hospital or in-hospital cardiac arrest
- Intervention: Placement of an advanced airway device
- Comparators: Bag-mask ventilation alone or with non–advanced airway interventions (primary); or another advanced airway device (secondary)
- Outcomes: Any clinical outcome
- Time frame: August 15, 2023, to May 22, 2024

Summary of Evidence

A SysRev was last done on this topic for 2024.[73,74] The complete EvUp is provided in Appendix B. No new pediatric studies were identified. There is insufficient evidence to support the conduct of a SysRev.

Treatment Recommendations (2024)

We suggest the use of bag-mask ventilation rather than tracheal intubation or supraglottic airway in the management of children during cardiac arrest in the out-of-hospital setting (weak recommendation, very low–certainty evidence).[73,74]

There is insufficient quality evidence to support any recommendation for or against the use of the bag-mask ventilation compared with tracheal intubation or supraglottic airway for in-hospital cardiac arrest.

The main goal of CPR is effective ventilation and oxygenation, by whatever means, without compromising the quality of chest compressions. We suggest that clinicians consider transitioning to an advanced airway intervention (supraglottic airway or tracheal intubation) when the team has sufficient expertise, resources, and equipment to enable placement to occur with minimal interruptions to chest compressions or when bag-mask ventilation is not providing adequate oxygenation and ventilation (good practice statement).[73,74]

Ventilation Rate With Advanced Airway During Cardiac Arrest (PLS 4120.02, SysRev 2024, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with out-of-hospital or in-hospital cardiac arrest (asphyxial or arrhythmic origin) and an advanced airway
- Intervention: Use of any specific respiratory rate
- Comparators: Compared with ventilation rate of 8 to 10 per minute
- Outcomes: Any clinical outcome
- Time frame: July 18, 2023, to September 30, 2024

Summary of Evidence

The complete EvUp is provided in Appendix B. No new pediatric studies were identified. An updated SysRev is not warranted.

Treatment Recommendations (2024)

There is currently no supporting evidence to make a treatment recommendation on a specific ventilatory rate in pediatric cardiopulmonary resuscitation with an advanced airway.[73,74]

For cardiac arrest that occurs with an advanced airway in place, the use of ventilatory rates >10 breaths per minute may be reasonable. The PLS Task Force suggests using ventilatory rates close to age-appropriate respiratory rates with avoidance of hypoventilation and hyperventilation (good practice statement).[73,74]

INTRA-ARREST: DEFIBRILLATION

Energy Doses for Pediatric Defibrillation During Resuscitation (PLS 4080.12, SysRev 2025)

Rationale for Review

Shockable ventricular arrhythmias—ventricular fibrillation (VF) and pulseless ventricular tachycardia (pVT)—are less frequently recorded in children than in adults but are associated with a higher survival rate than non-shockable rhythms. Early defibrillation is the foundation of treatment**,** but optimal energy doses for initial and subsequent shocks remain controversial, with notable differences in first shock dose recommendations by ILCOR member councils.[80,101] This SysRev was registered before initiation (PROSPERO Registration CRD42024548898). The full CoSTR is available on the ILCOR website.[102]

Population, Intervention, Comparator, Outcome, Study Design, and Time Frame

- Population: Infants and children (excluding newborn infants) in ventricular fibrillation or pulseless ventricular tachycardia during out-of-hospital or in-hospital cardiac arrest
- Intervention: Initial defibrillation dose approximating 2J/kg (1.5–2.5 J/kg)
- Comparators: Initial defibrillation dose of >2.5J/kg, <1.5J/kg or any other specified dose
- Outcomes:

- Critical: Survival to hospital discharge, ROSC
- Important: Termination of VF/pVT.

- Study designs: In addition to standard criteria, case series with a minimum of 5 cases were eligible for inclusion.
- Time frame: All years to September 1, 2024

Consensus on Science

Seven studies were included,[103-109] all of which were observational studies and provided very low certainty evidence (downgraded for imprecision and risk of bias) for the important and critical outcomes described. Key outcomes are summarized in Table 3.

Acknowledging the very low level of certainty, the current available data suggest that outcomes are not significantly better or worse when initial defibrillation doses of <2 J/kg or >2 J/kg are used for children in cardiac arrest with a shockable rhythm, compared with initial doses of approximately 2 J/kg.

Table 3. Summative Results of Studies: Pediatric Defibrillation Dose Systematic Review

Outcomes (Importance)	Participants (Studies), n	Certainty of Evidence (GRADE)	RR (95% CI)	ARD with Intervention
Defibrillation dose <2J/kg (I) compared with defibrillation dose approximating 2J/kg (C) for defibrillation in children in cardiac arrest				
Termination of VF/pVT (important)	265 (2 nonrandomized studies)[103,105]	Very low	RR 0.63 (0.14 to 2.84)	179 fewer per 1000 (from 415 fewer to 888 more)
ROSC (critical)	266 (4 nonrandomized studies)[104,106,108,109]	Very low	RR 1.06 (0.95 to 1.18)	51 more per 1000 (from 42 fewer to 152 more)
Survival to Hospital Discharge (critical)	225 (2 nonrandomized studies)[104,106]	Very low	RR 1.06 (0.80 to 1.40)	29 more per 1000 (from 96 fewer to 192 more)
Defibrillation dose >2J/kg (I) compared with defibrillation dose approximating 2J/kg (C) for defibrillation in children in cardiac arrest				
Termination of VF/pVT (important)	265 (2 nonrandomized studies)[103,105]	Very low	RR 0.96 (0.82 to 1.13)	22 fewer per 1000 (from 99 fewer to 77 more)
ROSC (critical)	596 (6 nonrandomized studies)[104-109]	Very low	RR 0.95 (0.77 to 1.17)	29 fewer per 1000 (from 133 fewer to 98 more)

Outcomes (Importance)	Participants (Studies), n	Certainty of Evidence (GRADE)	RR (95% CI)	ARD with Intervention
Survival to Hospital Discharge (critical)	225 (2 nonrandomized studies)[104,106]	Very low	RR 1.20 (0.38 to 3.77)	82 more per 1000 (from 253 fewer to 1000 more)

ARD indicates absolute risk difference; C, comparator; CI, confidence interval; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; I, intervention; pVT, pulseless ventricular tachycardia; RR, risk ratio; ROSC, return of spontaneous circulation; and VF, ventricular fibrillation.

Prior Treatment Recommendations (2020)

We suggest the routine use of an initial dose of 2 to 4 J/kg of monophasic or biphasic defibrillation waveforms for infants or children in VF or pVT cardiac arrest (weak recommendation, very low–quality evidence). There is insufficient evidence on which to base a recommendation for second and subsequent defibrillation doses.[110-112]

Treatment Recommendations (2025)

In the absence of evidence to demonstrate a clear preference for any particular energy dose, we suggest the use of an initial defibrillation dose of 2 to 4 J/kg for infants or children in VF or pVT cardiac arrest (weak recommendation, very low–certainty evidence).

This review did not investigate the evidence for second and subsequent defibrillation dosages.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

Differences remain in the first shock dose recommended by ILCOR member councils, with the European Resuscitation Council and Australian and New Zealand Committee on Resuscitation recommending 4J/kg for first and all subsequent shockshttps://www.ahajournals.org/doi/full/10.1161/CIR.0000000000000894?rfr_dat=cr_pub++0pubmed&url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org and the American Heart Association recommending an initial dose of 2 to 4 J/kg (for ease of teaching, a dose of 2 J/kg is used in algorithms and training materials). For refractory VF, American Heart Association guidelines recommend

increasing defibrillation dose to 4 J/kg, suggesting that subsequent energy doses should be at least 4 J/kg and noting that higher levels may be considered, not to exceed 10 J/kg.

The task force recognized that most studies were conducted in sites where either 2 J/kg or 4 J/kg doses were recommended for initial defibrillation. The variability of dosing was largely attributable to the few energy dose settings on defibrillators. So, although no specific energy dose was found superior, energy selections would generally have been approximating either 2 or 4 J/kg.

Knowledge Gaps

- Whether there are any specific undesirable effects (eg, myocardial damage) of defibrillation with the different doses studied
- Prehospital and in-hospital studies, ideally comparing existing different dosing strategies with planned subgroup analyses based on patient age and type of shockable rhythm (primary versus secondary) are ethical, necessary, and critically important to help guide clinicians in making these complex decisions. As different resuscitation councils recommend either 2 or 4 J/kg as an initial defibrillation dose, this may provide an opportunity for an international comparative study.
- Potential adverse effects of higher defibrillation doses when fixed energy doses are provided (eg, through use of AEDs)
- Effect of different defibrillation energy doses on clinically important outcomes[4]

Paddle/Pad Size and Placement in Infants and Children (PLS 4080.17, SysRev 2025)

Rationale for Review

Definition of proper pad positioning and size to anatomically encompass the heart and ensure good contact is vital in pediatric defibrillation. The PLS Task Force's previous review of defibrillation strategies[5] showed no clear superiority for vector change or double-sequential strategies but reinforced

the critical importance of proper pad placement. Since this review, a randomized trial[114] and retrospective observational study[115] have been published, prompting this SysRev[116] The SysRev was registered before initiation (PROSPERO Registration CRD42024512443) and conducted in partnership with the BLS and ALS Task Forces. The full CoSTR can be found on the ILCOR website and in the BLS section.[117]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Adults and children in any setting (in-hospital or out-of-hospital) with cardiac arrest and a shockable rhythm at any time during cardiopulmonary resuscitation (CPR)
- Intervention: The use of any specific pad size, orientation, and position
- Comparators: Reference standard pad size, orientation, and position
- Outcomes:
  - Critical: Survival with favorable neurological outcome at hospital discharge or 30-days; survival at hospital discharge or 30 days
  - Important: ROSC; termination of VF; rates of defibrillation
- Time frame: All years to September 22, 2024

Consensus on Science

No pediatric studies were identified that addressed the questions of defibrillator pad size, orientation, or placement.

Due to the lack of direct evidence in infants and children, the PLS Task Force used the very low–certainty evidence from adult studies, downgraded for indirectness, to inform the treatment recommendations. Details of the adult evidence are available in the BLS CoSTR publication.[118]

Prior Treatment Recommendations (2010)

There is insufficient evidence to alter the current recommendations to use the largest size paddles that fit an infant's or child's chest without touching each other or to recommend one paddle or pad position or type over another.[110,119]

Treatment Recommendations (2025)

For Manufacturers

Manufacturers could consider the standardization of pads size for infants, children, and adults (good practice statement).

Manufacturers of AEDs should standardize pad placement in an anteroposterior position for infants and young children (with 1 pad anteriorly, over the left precordium, and the other pad posteriorly to the heart just inferior to the left scapula) (good practice statement).

Manufacturers should include instructions to ensure adequate contact between the pad and the skin and ensure that their pad position diagrams clearly indicate the ILCOR-recommended pad position (good practice statement).

For CPR Providers Using an AED

Follow the AED specific guidance and instructions for pads placement in infants and children (good practice statement).

For CPR Providers Trained in Manual Defibrillation

In infants and children, place pads in an anterior-posterior position (good practice statement).

Vector Change Strategy

We cannot make a recommendation for or against the use of vector change strategy for the treatment of refractory VF or pulseless VT in infants and children.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

Due to the lack of direct evidence in infants and children, and the very low certainty of the indirect evidence from adults, the task force was unable to make treatment recommendations for CPR providers using AEDs or manual defibrillators. The task force decision to provide a good practice statement suggesting positioning pads in the AP position was based on the indirect evidence on adults that it improves ROSC. However, the task force did recognize the very low certainty of the evidence from this observational study.[120]

In making these recommendations, the PLS Task Force recognized that AP positioning of pads is easier in infants and children than in adults. Pads may also be used as real-time feedback devices for quality assessment of chest compressions. In these circumstances, pads generally need to be in the AP position. The AP position is not feasible with paddles, which are still used in some low-resource settings.

Knowledge Gaps

- No studies examined the pediatric or in-hospital setting.
- The effectiveness of different pad positions compared with standard positions in any patient population, in the first 3 shocks
- The relative effectiveness of different pad sizes
- The interaction between pad size and pad orientation
- The effectiveness of a vector change strategy in children

Single or Stacked Shocks for Pediatric Defibrillation (PLS 4080.19, SysRev 2025)

Rationale for Review

Before 2005, guidelines recommended 3 stacked shocks for shockable rhythms because of low first-shock efficacy with monophasic waveforms and the theoretical reduction in transthoracic impedance after each shock.[121] However, with the advent of biphasic defibrillators, which show high first-shock success and minimal transthoracic impedance reduction, the 2005 guidelines shifted to a single-shock strategy followed by immediate chest compressions.[122,123]

Current ILCOR guidelines, unchanged since 2010, endorse a single-shock approach followed by CPR for pediatric VF or pVT, before reassessing rhythm. EvUps done in 2023 found no new pediatric studies, and adult studies were excluded because of physiological differences between children and adults.[124,125] The PLS Task Force prioritized this SysRev to enable confirmation of current recommendations through a systematic search. The SysRev was registered before initiation (PROSPERO Registration: CRD42024559428) and the full CoSTR is available online.[126]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) who are in VF or pVT during out-of-hospital or in-hospital cardiac arrest
- Intervention: More than 1 (stacked) shocks for the initial or subsequent defibrillation attempt
- Comparison: A single shock for each defibrillation attempt
- Outcomes: Any clinical outcome
- Time frame: All years to May 15, 2024

Consensus on Science

No studies comparing single versus stacked shock in children with out-of-hospital or in-hospital cardiac arrest with VF or pVT were identified.

Prior Treatment Recommendations (2005, Withdrawn)

A single-shock strategy followed by immediate CPR (beginning with chest compressions) is recommended for children with out-of-hospital or in-hospital VF or pVT.

The prior treatment recommendation of 2005 is unsupported due to the lack of any available direct or indirect evidence. The PLS Task Force therefore withdraws the prior treatment recommendation and replaces it with a good practice statement.

Treatment Recommendations (2025)

In infants and children with out-of-hospital or in-hospital cardiac arrest in VF or pVT, we suggest a single-shock strategy followed by immediate CPR (beginning with chest compressions) (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

The 3-shock (stacked) strategy used in pediatric VF or pVT before the 2005 American Heart Association guideline was based on an extrapolation from advanced cardiovascular life support recommendations in adults. The 1-shock strategy has not been directly studied against a 3-shock strategy in pediatric VF/pVT but the 2005 recommendation[127] that providers should give a single shock followed immediately by CPR (beginning with chest compressions) rather than the 3 successive ("stacked") shocks in pediatric VF or pVT was based on the evidence that

- First-shock success rate of currently used biphasic defibrillators is up to 90%.[128,129]
- In a 3-shock sequence (stacked) the delay between delivery of the first shock and delivery of the first post-shock compression is up to 37 seconds.[130,131]
- Interruption of chest compressions reduces coronary perfusion pressure.[132]

- If the first shock fails, intervening chest compressions may improve oxygen and substrate delivery to the myocardium, making the subsequent shock more likely to result in defibrillation.
- Data from animal studies document harmful effects from interruptions to chest compressions.[133]

Knowledge Gaps

There are no randomized controlled trials directly comparing 3-shock (stacked) strategy with single biphasic shocks in pediatric defibrillation.

Lay Rescuer Use of AEDs (PLS 4080.01, SysRev 2022, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with non-traumatic OHCA
- Intervention: Application of or shock delivery from an AED by lay rescuers
- Comparators: Standard care by lay rescuer without AED application
- Outcomes: Any clinical outcome
- Time frame: November 3, 2021, to May 22, 2024

Summary of Evidence

The complete EvUp is provided in Appendix B. A SysRev of this topic was last done for the 2022 CoSTR summary.[70-72] This EvUp identified no new pediatric studies on this subject that would potentially alter the current treatment recommendation. There is insufficient evidence to support the conduct of a SysRev.

Treatment Recommendations (2022)

We suggest the use of an AED by lay rescuers for all children >1 year of age who have nontraumatic OHCA (weak recommendation, very low–certainty evidence).[70-72]

We cannot make a recommendation for or against the use of an AED by lay rescuers for all children <1 year of age with nontraumatic OHCA.[70-72]

INTRA-ARREST: MONITORING

Pulse Check Accuracy in Pediatrics During Resuscitation (PLS 4080.18, SysRev 2025)

Rationale for Review

Guidelines recommend a manual pulse check during rhythm analyses to detect ROSC, with different anatomical sites for different age groups.[134] With the increasing availability of ultrasound and arterial lines, the PLS Task Force prioritized this topic and conducted the first SysRev based on a previous EvUp in 2023.[135] The SysRev was registered before initiation (PROSPERO Registration CRD42024549535). The full CoSTR can be found on the ILCOR website.[136]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children in any setting (out-of-hospital or in-hospital) with suspected cardiac arrest when assessing whether to start or continue CPR
- Intervention: Any other site for pulse check (eg femoral pulse) OR method (including but not limited to cardiac auscultation, pulse oximetry, ultrasonography, rise in end-tidal CO_2 values above specific thresholds, invasive monitoring)
- Comparators: Pulse check as per current guidelines for healthcare professionals (brachial pulse for infants and carotid pulse for children and adolescents)
- Outcomes: Any outcome including but not limited to
  - Accuracy, defined as sensitivity and specificity of detecting a perfusing rhythm
  - Duration of cardiac compression pauses
  - Any clinical outcome
- Time frame: All years to April 24, 2024

Consensus on Science

Accuracy

For the critical outcome of accuracy (defined as sensitivity and specificity), this SysRev identified 3 studies with 39 patients and 376 pulse checks, providing very low certainty of evidence.[137-139] All studies had a serious risk of bias. Two studies were further downgraded for imprecision and indirectness. These studies assessed clinicians' ability to accurately palpate a pulse (brachial or femoral) for children with LVADs or on ECMO, but without cardiac arrest. Sensitivity ranged from 76% to 100%, and specificity 64% to 79%.[137,138] The studies did not directly compare different pulse palpation sites.

Duration of Cardiac Compression Pauses

No studies in infants and children were identified that directly assessed this outcome. One study evaluated the time until a decision was made about whether a pulse was present or not. However, this study was performed in children with LVADs or on ECMO with arterial blood pressure monitoring blinded for the participants.[138] In this study, only 39% (60/153) of the participants decided on the presence of a pulse within 10 seconds. The median duration until any decision was made was 18 seconds, with an accuracy of 85%. Inexperienced providers took longer to make their decisions. This indirect evidence indicates that there is a reasonable concern about prolonged chest compression pauses, especially in inexperienced clinicians. This evidence was gained in a less critical setting with perfused children with warm skin temperature and brisk capillary refill time.

Any Clinical Outcome

No studies in infants and children were identified that assessed any clinical outcome.

Prior Treatment Recommendations (2020)

Palpation of a pulse (or its absence) is not reliable as the sole determinant of cardiac arrest and need for chest compressions. If the victim is unresponsive, and not breathing normally, and there are no signs of life, lay rescuers should begin CPR.[110]

Withdrawn Treatment Recommendation

In infants and children with no signs of life, healthcare providers should begin CPR unless they can definitely palpate a pulse within 10 seconds.

Treatment Recommendations (2025)

We suggest that the palpation of a pulse (or its absence) is unreliable as the sole determinant of cardiac arrest and the need for chest compressions (weak recommendation, very low certainty on evidence).

In unresponsive children, not breathing normally and without signs of life, lay rescuers and healthcare professionals should begin CPR (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete Evidence-to-decision table is provided in Appendix A.

The task force justified including the 2 previously included studies in the SysRev, downgrading those studies for indirectness.[137,138] One additional case series showed good accuracy when ultrasound was performed by trained providers for emergency department resuscitation of children with cardiac arrest during pulse checks.[139] Very experienced providers performed the intervention in this case series. The task force concluded that evidence was insufficient to make a treatment recommendation. The duration of pulse checks was not reported in this case series.

The previous treatment recommendation limited the pulse check duration to 10 seconds.[119] However, in 1 study, only 39% (60/153) of the participants decided on the presence of a pulse within

10 seconds.[138] Given the indirect evidence in this SysRev, the task force withdrew the Treatment Recommendation regarding pulse palpation within 10 seconds.

Knowledge Gaps

- No randomized controlled trials were identified comparing ultrasound, arterial blood pressure or different pulse check sites with guideline recommended pulse check sites in children with cardiac arrest.
- Further examination of the potential longer hands-off time and impact on outcome.
- Future studies would benefit from including outcome measures consistent with the P-COSCA recommendations.[4]

Blood Pressure Monitoring and Targets During Pediatric In-Hospital Cardiac Arrest (PLS 4160.08, SysRev 2025)

Rationale for Review

In children who have intra-arterial catheters in place, hemodynamic data may be used to provide information about the quality of chest compressions during cardiac arrest.[140] Since the PLS Task Force ScopRev in 2020[141], subsequent studies on the topic[142,143] have been published, prompting this SysRev.[144] The SysRev was registered with PROSPERO prior to initiation (Registration CRD42024590080), and the full CoSTR can be found on the ILCOR website.[145]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children receiving resuscitation after in-hospital cardiac arrest with intra-arterial blood pressure monitoring in place at the time of arrest
- Intervention: A specific blood pressure target during arrest
- Comparators: A different blood pressure target or no blood pressure target

- Outcomes: Critical: ROSC; survival to hospital discharge; survival to hospital discharge with good neurological outcome
- Time frame: All years to July 19, 2024

Consensus on Science

Five observational cohort studies were included.[142,146-149] Three were analyses of the same cohort (Pediatric Intensive Care Quality of CPR study) but examined different subpopulations or different outcomes.[146,148,149]

Diastolic Blood Pressure

For the critically important outcomes of ROSC, survival to hospital discharge, and survival with favorable neurological outcome, we identified 2 observational studies enrolling 577 patients with IHCA and invasive arterial blood pressure monitoring in place at the time of arrest,[142,146] which showed benefit from exposure to diastolic blood pressure (DBP) of ≥25 mm Hg for infants <1 and ≥30 mm Hg for children ≥1 for the first 10 minutes of CPR, when compared with lower DBP. A summary of the outcomes of the included studies examining DBP targets is shown in Table 4.

Table 4. Summative Results of Studies: Pediatric Diastolic BP Targets

Outcomes (Importance)	Participants (Studies), n	Certainty of Evidence (GRADE)	RR (95% CI)	Anticipated absolute effect* (95% CI)	
				Risk with no BP target	Risk with a DBP of 25mm Hg for infants <1 and 30mm Hg for children >=1
Return of spontaneous circulation (critical)	577 (2 non-randomized studies)[142,146]	Very low	RR 1.33 (1.12–1.59)	528 per 1000	703 per 1000 (592–840)
Survival to hospital discharge (critical)	577 (2 non-randomized studies)[142,146]	Very low	RR 1.55 (1.18–1.91)	407 per 1000	630 per 1000 (480–776)
Survival with favorable neurological outcome (PCPC 1-3 or no change from baseline) (critical)	577 (2 non-randomized studies)[142,146]	Very low	RR 1.37 (1.04–1.69)	390 per 1000	535 per 1000 (406–660)

Outcomes (Importance)	Participants (Studies), n	Certainty of Evidence (GRADE)	RR (95% CI)	Anticipated absolute effect* (95% CI)	
				Risk with no BP target	Risk with a DBP of 25mm Hg for infants <1 and 30mm Hg for children >=1
Functional status scale[150] increase by 3 or increase by 2 in single domain (in survivors) (critical)	77 (1 non-randomized study)[148]	Very low	RR 1.69 (0.83–3.42)	222 per 1000	376 per 1000 (184–760)

*The risk in the intervention group (and its 95% CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).
CI indicates confidence interval; DBP, diastolic blood pressure; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; PCPC, Pediatric Cerebral Performance Category; and RR, risk ratio.

There was no difference in median DBP between subjects with new substantive morbidity after arrest and those without (30.5 mm Hg versus 30.9 mm Hg, p=0.5).[148] This was a subpopulation of the subjects in Berg et al (2018).[146]

Diastolic Blood Pressure: Subgroups

For the critically important outcome of survival to hospital discharge, we identified very low–certainty evidence from a single observational study enrolling children with invasive arterial BP monitoring in place at the time of IHCA, and either medical cardiac disease (n=24) or surgical cardiac disease (n=88).[149] Only patients with surgical cardiac disease had improved survival to hospital discharge (RR 1.64; 95% CI 1.06–2.54) from exposure to a DBP of ≥25 mm Hg for infants <1 and ≥30 mm Hg for children ≥1 for the first 10 minutes of CPR when compared with patients with lower DBP.

Systolic Blood Pressure

For the critically important outcomes of survival to hospital discharge and survival with favorable neurological outcome, we identified no difference from exposure to a systolic blood pressure of ≥60 mm Hg for infants <1 and ≥80 mm Hg for children ≥1 for the first 10 minutes of CPR (I) when compared with lower systolic blood pressure.[142,146] A summary of the outcomes of the included studies examining systolic BP targets is shown in Table 5.

Table 5. Summative Results of Studies - Pediatric Systolic BP Targets

Outcomes (Importance)	Participants (Studies), n	Certainty of Evidence (GRADE)	RR (95% CI)	Anticipated absolute effect* (95% CI)	
				Risk with no BP target	Risk with a SBP of 60mm Hg for infants < 1 and 80mm Hg for children >=1
Survival to hospital discharge (critical)	577 (2 non-randomized studies)[142,146]	Very low	RR 1.12 (0.95 to 1.32)	507 per 1000	568 per 1000 (482 to 670)
Survival with favorable neurological outcome (PCPC 1-3 or no change) (critical)	164 (1 non-randomized study)[146]	Very low	RR 1.0 (0.7 to 1.4)		
Functional status scale increase by 3 or increase by 2 in single domain (in survivors) (critical)	77 (1 non-randomized study)[148]	Very low	RR 0.70 (0.40 to 1.24)	489 per 1000	342 per 1000 (196 to 606)

*The risk in the intervention group (and its 95%CI) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI).
CI indicates confidence interval; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; PCPC, Pediatric Cerebral Performance Category; RR, risk ratio; and SBP, systolic blood pressure.

There was no difference between the median systolic blood pressure between subjects with new substantive morbidity and those without (76.3 mm Hg versus 63 mm Hg, p = 0.2). [148] This was a subpopulation of the subjects in Berg et al (2018).[146]

Presence of Monitoring

No difference was found in any of the outcomes in the single study[147] examining clinician-reported use of invasive blood pressure for monitoring of CPR quality compared with no use of monitoring.

Prior Treatment Recommendations (2020)

The confidence in effect estimates is so low that the panel decided a recommendation was too speculative.

Treatment Recommendations (2025)

We suggest targeting an intra-arrest diastolic blood pressure of ≥25 mm Hg for infants <1 year and ≥30 mm Hg for children 1 to 18 years with invasive blood pressure monitoring in place at the time of cardiac arrest (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete Evidence-to-decision table is provided in Appendix A.

Measurement of intra-arrest blood pressure is generally available only in high-resource settings, and all studies examined patients with invasive BP monitoring in place at the time of arrest. While this limits the scope of the recommendation, children with invasive BP monitoring may be at higher risk of cardiac arrest, thus making a recommendation valuable.

No randomized controlled trials were identified in the search. We found only very low–certainty evidence from 5 observational trials, all of which were from cohorts in the United States (ICU-RESUSCITATION[143], Pediatric Intensive Care Quality of CPR study[146], and Get With the Guidelines-Resuscitation). Other studies[146,148,149] all used the Pediatric Intensive Care Quality of CPR study cohort but with different subpopulations or outcome measures.

The task force noted that in Berg et al (2018), the same population was used to both generate and validate the cutoffs of 25 mm Hg and 30 mm Hg for infants and children, respectively.[146] Berg et al (2023)[142] examined other cutoffs but found 25 mm Hg and 30 mm Hg to be most predictive. We noted that while Berg et al (2018) showed a benefit in functional neurological outcome (aRR 1.6; 95% CI 1.1–2.5), Berg et al (2023) did not (aRR 1.14; 95% CI 0.93–1.39). The pooled estimate suggested benefit (aRR 1.37; 95% CI 1.04–1.69). Lastly, we noted that certain subgroups were under-represented, including children with heart disease and older children.

Since the evidence is both indirect and imprecise, as described above, the task force limited the recommendation to children with invasive BP monitoring in place at the time of arrest.

Knowledge Gaps

- Randomized trial data comparing the benefits or harms of specific BP targets during arrest
- Use of non-invasive methods to measure BP during arrest
- Whether different blood pressure targets would be more appropriate for older children or adolescents
- The utility of initiating invasive BP monitoring intra-arrest
- Blood pressure targets in children with heart disease
- The importance of diastolic and systolic BP in longer arrests, as studies have focused primarily on BP in the first 10 minutes of CPR
- The effect of mean arterial pressure on outcomes

Intra-arrest Echocardiography (Point-of-Care Cardiac Ultrasound) (PLS 4160.05, ScopRev 2020, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with cardiac arrest.
- Intervention: The presence of variables (images, cut-off values or trends) during CPR (intra-arrest) that can provide physiologic feedback to guide resuscitation efforts, namely: echocardiography/point-of-care cardiac ultrasound
- Comparators: The absence of such variables (images, cut-off values or trends)
- Outcomes: Any clinical outcome
- Time frame: July 2020 to June 26, 2024

Summary of Evidence

A ScopRev was done in 2020,[110-112] with an EvUp in 2023[124,125] and for 2025. The 2025 EvUp is included in Appendix B, and neither EvUp since 2020 identified any new pediatric studies on this

subject that would inform a treatment recommendation. There is insufficient evidence to support a SysRev.

Good Practice Statement (2025)

The Treatment Recommendation of 2010,[151,119] which was reiterated in 2020[110-112], has been downgraded to a good practice statement based the lack of evidence.

For children in cardiac arrest, echocardiography may be considered to identify potentially treatable conditions when appropriately skilled personnel are available, but the benefits must be carefully weighed against the known deleterious consequences of interrupting chest compressions (good practice statement).

Intra-arrest End-Tidal Carbon Dioxide (PLS 4160.07, ScopRev 2020, EvUp 2025)

Population, Intervention, Comparator, Outcome, Study Design, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest
- Intervention: The presence of variables (images, cut-off values or trends) during CPR (intra-arrest) that can provide physiologic feedback to guide resuscitation efforts, namely: end-tidal carbon dioxide ($ETCO_2$)
- Comparators: The absence of such variables (images, cut-off values or trends)
- Outcomes: Any clinical outcome
- Time frame: July 2020 to June 26, 2024

Summary of Evidence

This topic was previously reviewed in a ScopRev for 2020,[110-112] with an EvUp in 2023[124,125] and for 2025. The complete 2025 EvUp is provided in Appendix B. One observational study published in 2022 demonstrated an association between $ETCO_2$ monitoring and ROSC in adolescents.[152] A

propensity weighted cohort study[147] concluded that clinician reported use of $ETCO_2$ intra-arrest was not associated with ROSC in children. The ICU-RESUS trial was a large multicenter prospective observational cohort study. A secondary analysis study of ICU-RESUS trial found no association between $ETCO_2$ in first 10 min CPR event and survival with favorable neurologic outcome.[153] However, an ancillary study of children in ICU-RESUS trial (CPR-NOVA)[154] found a higher incidence of ROSC and survival to hospital discharge in patients with $ETCO_2$ target >20 mm Hg. It is the first pediatric study to support use of $ETCO_2$ monitoring intra-arrest and defines an intra-arrest $ETCO_2$ target. A SysRev may be justified following future studies assessing this question.

Good Practice Statement (2025)

The Treatment Recommendation of 2015 [155], reiterated in 2020, has been downgraded to a good practice statement based on the lack of evidence.

There is insufficient evidence to recommend for or advise against a treatment recommendation related to intracardiac arrest $ETCO_2$ monitoring.

For children in cardiac arrest monitoring $ETCO_2$ may help achieve quality CPR; however, specified values to guide intra-arrest interventions have not been well established (good practice statement).

Intra-arrest Near-Infrared Spectroscopy (PLS 4160.09, ScopRev 2020, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest
- Intervention: The presence of variables (images, cut-off values or trends) during CPR (intra-arrest) that can provide physiologic feedback to guide resuscitation efforts, namely near infrared spectroscopy
- Comparators: The absence of such variables (images, cut-off values or trends)

- Outcomes: Any clinical outcome
- Time frame: July 2020 to June 26, 2024

Summary of Evidence

This topic was last reviewed in a ScopRev for the 2020 CoSTR. The complete EvUp is provided in Appendix B. We identified 1 additional abstract[156] and a single center observational study by the same authors utilizing data from 3 hospitals in the Pediatric Resuscitation Quality Collaborative.[157] Both studies concluded that higher median cerebral regional oxygen saturation measured with cerebral near infrared spectroscopy during IHCA in children was associated with increased rate of ROSC and survival to hospital discharge. A SysRev is not indicated at this time.

Good Practice Statement (2025)

The treatment recommendation of 2020[110-112] has been downgraded to a good practice statement based on the lack of evidence.

Monitoring cerebral oxygenation during cardiopulmonary resuscitation is a non-invasive metric that does not require pulsatile signal and may be beneficial to monitor. However, there is no consensus about a cut-off threshold for cerebral oxygenation that can be used to guide or terminate resuscitation during in-hospital cardiac arrest in children (good practice statement).

INTRA-ARREST: DRUGS AND DRUG ADMINISTRATION

Vasopressor Use During Cardiac Arrest in Children (PLS 4080.21, SysRev 2025)

Rationale for Review

Since the SysRev published by the ILCOR PLS Task Force CoSTR in 2020 on timing of epinephrine initial dose and dose interval during CPR in children,[110-112] a systematic review[158] and 3 observational studies[159-161] have been published examining the effects of Epinephrine in pediatric cardiac arrest. The PLS Task Force therefore prioritized an updated SysRev, which was registered

before initiation (PROSPERO Registration CRD42024596959). The full CoSTR is available on the ILCOR website.[162]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (<18 years) in cardiac arrest who received chest compression in any setting
- Intervention: Any use of vasopressors (epinephrine, vasopressin, combination of vasopressors)
- Comparators: No vasopressor use
- Outcomes:
  - Critical: Short-term and long-term survival or neurological outcomes.
  - Important: ROSC.
- Time frame: All years to July 16, 2024

Consensus on Science

Two propensity score matched observational studies were identified[159,163], providing very low– to low–certainty evidence. Both studies were in the out-of-hospital setting and compared outcomes of children who received epinephrine with children who did not.

For favorable neurological outcomes at 1 month, 1 study[161] involving 608 patients found no significant difference when epinephrine was administered compared with no epinephrine (15 more patients with favorable neurological survival at 1-month per 1000 resuscitations; 95 CI%: 11 fewer to 92 more).[161]

For favorable neurological outcome at hospital discharge, the second study,[159] involving 1432 patients, found no significant difference when epinephrine was administered compared with no epinephrine (9 more patients with favorable neurological survival at hospital discharge per 1000 resuscitations; 95 CI%: 13 fewer to 50 more).

For survival at 1 month, 1 study[161] involving 608 patients found no significant difference when epinephrine was administered compared with no epinephrine (10 more survivor per 1000 resuscitations; 95 CI%: 27 more to 78 more).

For survival to hospital discharge, 1 study[159] involving 1432 patients found no significant difference when epinephrine was administered compared with no epinephrine (19 more survivor per 1000 resuscitations; 95 CI%: 7 fewer to 64 more).

For pre-hospital ROSC, 2 studies[159,161] involving 2034 patients found a benefit when epinephrine was administered, compared with no epinephrine (63 more patients with ROSC per 1000 resuscitations; 95 CI%: 28 more to 145 more).

Prior Treatment Recommendations (2020)

We suggest that the initial dose of epinephrine in pediatric patients with non-shockable IHCA and OHCA be administered as early in the resuscitation as possible (weak recommendation, very low–certainty evidence).

We cannot make a recommendation for the timing of the initial epinephrine dose in shockable pediatric cardiac arrest. The confidence of the effect estimates is so low that we cannot make a recommendation about the optimal interval for subsequent epinephrine doses in pediatric patients with IHCA or OHCA.

Treatment Recommendations (2025)

We suggest the use of epinephrine in pediatric out-of-hospital cardiac arrest (weak recommendation, very low–certainty evidence).

There is insufficient evidence to generate a treatment recommendation for the use of epinephrine in pediatric in-hospital cardiac arrest. However, the task force considers the indirect evidence from OHCA to support the administration of epinephrine in pediatric in-hospital cardiac arrest (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete Evidence-to-decision table is provided in Appendix A.

The task force acknowledged that the included studies were from settings with advanced emergency medical services. In similar settings, the administration of epinephrine as part of advanced pediatric life support for pediatric OHCA should be continued but also further evaluated.

However, there are very few studies looking at resources required to train, maintain skillsets, and provide the necessary equipment for emergency medical services systems to administer epinephrine in pediatric OHCA.

The task force acknowledged that the ALS Task Force currently recommends the use of epinephrine in adult cardiac arrest. The PLS Task Force did not include indirect evidence from adults because of differences in etiologies of cardiac arrest in children.[159,161,164]

Knowledge Gaps

- The effect of potential undesirable effects of epinephrine. Adverse outcomes from administration of epinephrine have been reported.[160]
- Whether specific subpopulations might potentially benefit (or not) from administration of epinephrine in the pre-hospital setting.
- Cost-effectiveness and feasibility of the provision of advanced pediatric life support in the pre-hospital settings (across resource rich and limited emergency medical services systems) to facilitate the administration of epinephrine in pediatric OHCA while ensuring high-quality basic life support.
- Effect of vasopressors during cardiac arrest in the inpatient setting, especially in the context of initial resuscitation of pediatric cardiac arrest patients prior to ECPR.[165,166]

Epinephrine Administration Timing in Cardiac Arrest (PLS 4090.02, SysRev 2020, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest
- Intervention: Administration of the initial dose of epinephrine earlier or later than current guideline recommendations; or administration of epinephrine more or less frequently than every 3-5 minutes following the initial dose
- Comparators: Timing of administration of epinephrine in line with current guideline recommendations
- Outcomes: Any clinical outcome
- Time frame: July 2019 to April 25, 2024

Summary of Evidence

The complete EvUp is provided in Appendix B. This topic was last updated by a SysRev for the 2020 CoSTR.[110-112] This EvUp identified 5 new pediatric observational studies on this subject since the last review.[159,166,167], [168,169] Given the lack of a recommendation for epinephrine dosing intervals, a future SysRev may be warranted. However, no evidence for the time to first dose epinephrine in shockable rhythms was identified and a SysRev for this question is not justified.

Treatment Recommendation (2020)

We suggest the initial dose of epinephrine in pediatric patients with both non-shockable IHCA and OHCA be administered as early in the resuscitation as possible (weak recommendation, very low–certainty evidence).[110-112]

We cannot make a recommendation for the timing of the initial epinephrine dose in shockable pediatric cardiac arrest.

The confidence of the effect estimates is so low that we cannot make a recommendation regarding the optimal epinephrine interval for subsequent epinephrine doses in pediatric patients with IHCA or OHCA.

Calcium Use During Cardiac Arrest (PLS 4090.01, SysRev 2023, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest
- Intervention: Calcium administration
- Comparators: No calcium administration
- Outcomes: Any clinical outcome
- Time frame: November 2019 to October 26, 2024

Summary of Evidence

A SysRev on this topic was published[170] for the 2023 CoSTR summary.[124,125] The 2025 EvUp is provided in Appendix B. We identified 2 additional observational studies in children, both of which found a significantly lower rate of sustained ROSC, lower survival rate to hospital discharge and lower survival to discharge with favorable neurologic outcome associated with use of calcium in arrest.[171,172] There is insufficient evidence to support a new SysRev.

The use of calcium for documented hypocalcemia, hypermagnesemia, or suspected calcium channel blocker overdose was not included in this review. Further evaluation of the use of calcium in these special circumstances is required. The use of calcium in hyperkalemia is reviewed separately.

Treatment Recommendation (2020)

Routine use of calcium for infants and children with cardiopulmonary arrest is not recommended in the absence of hypocalcemia, calcium channel blocker overdose, hypermagnesemia, or hyperkalemia.[110-112]

Sodium Bicarbonate Administration in Cardiac Arrest (PLS 4090.04, EvUp 2020, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest
- Intervention: Use of sodium bicarbonate with a certain dose and timing
- Comparators: No sodium bicarbonate
- Outcomes: Any clinical outcome
- Time frame: December 1, 2020, to October 21, 2024

Summary of Evidence

An EvUp was done for the 2020 CoSTR,[110-112] and the treatment recommendation from 2010 was maintained. The current EvUp identified 2 pediatric studies, 1 a meta-analysis[173] and the other, a secondary analysis of a prospective RCT.[174] Both found sodium bicarbonate administration during pediatric cardiac arrest was associated with a significantly decreased rate of survival to hospital discharge. The complete EvUp is provided in Appendix B. Based on this EvUp, we plan to conduct a systematic review.

Treatment Recommendation (2010)

Routine administration of sodium bicarbonate is not recommended in the management of pediatric cardiac arrest.[151/110-112,119]

Anti-Arrhythmic Drugs in Cardiac Arrest With Shockable Rhythms (PLS 4080.04, SysRev 2018, EvUp 2023, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest and a shockable rhythm at any time during CPR or immediately after ROSC
- Intervention: Administration (IV or IO) of an anti-arrhythmic drug
- Comparators: Administration of another anti-arrhythmic or placebo
- Outcomes: Any clinical outcome
- Time frame: July 5, 2022, to October 1, 2024

Summary of Evidence

This topic was last reviewed with a SysRev in 2018[175-177] and EvUp in 2023.[124,125] The complete EvUp is provided in Appendix B. Our EvUp identified no new pediatric studies on this subject. There is insufficient evidence to support the conduct of a systematic review.

Treatment Recommendation (2018)

We suggest that amiodarone or lidocaine may be used for the treatment of pediatric shock–resistant VF/pVT (weak recommendation, very low–quality evidence).[176,177]

IO Versus IV in Cardiac Arrest (PLS 4080.15, SysRev 2020, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest
- Intervention: Placement of an IO cannula and drug administration through this IO during cardiac arrest

- Comparators: Placement of an IV cannula and drug administration through this IV during cardiac arrest
- Outcomes: Any clinical outcome
- Time frame: September 1, 2019, to May 10, 2024

Summary of Evidence

A SysRev on this topic was last conducted in 2020, and no evidence in children was found at that time so the 2010 recommendation was maintained.[110-112] The EvUp for 2025 also identified no new pediatric studies. The ALS Task Force conducted a SysRev[178] for this PICOST for 2025 but the PLS Task Force agreed that the adult evidence is too indirect to be considered relevant to the infant and child population. The adult evidence may have some relevance to the adolescent population and may be explored by the task force in the future.

Treatment Recommendation (2020, Unchanged From 2010)

Intraosseous cannulation is an acceptable route of vascular access in infants and children with cardiac arrest. It should be considered early in the care of critically ill children whenever venous access is not readily available.[110-112]

INTRA-ARREST: SPECIAL CIRCUMSTANCES

Cardiopulmonary Resuscitation in Obese Patients (ScopRev 2025)

Rationale for Review

This topic was chosen as a ScopRev by the PLS and BLS Task Forces because of the increasing prevalence of obesity worldwide and the specific challenges in providing cardiopulmonary resuscitation to this patient cohort. This topic has not previously been reviewed by ILCOR. The full ScopRev report is available online.[179]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Adults and children in any setting (in-hospital or out-of-hospital) with cardiac arrest
- Intervention: Cardiopulmonary resuscitation (including mechanical and ECPR) in obese patients (as defined in specific papers)
- Comparators: May have no comparator, comparator of non-obese patients, or comparator of modified CPR for obese patients with standard CPR
- Outcomes:
  - Critical: survival to hospital discharge with good neurological outcome and survival to hospital discharge.
  - Important: ROSC, CPR quality measures (chest compression rate, chest compression depth, ventilation rate, tidal volume, end-tidal CO2), CPR timing (time to commencement of rescue breaths, first compression, first defibrillation if shockable rhythm), CPR techniques (chest compressions, defibrillation, ventilation and airway management, vascular access and medications), health related quality of life and provider outcomes (safety, manual handling).
- Time frame: All years to October 1, 2024

Summary of Evidence

Adult evidence is summarized in the BLS CoSTR paper.[118] There were 2 studies of children[180,181] and 1 study in which patient age was not reported.[182] Both pediatric studies[180,181] reported worse neurological outcomes in obese children (compared with normal weight children) at hospital discharge[181] and 12 months.[180]

Survival to hospital discharge was reported in one pediatric study[181] in which survival to hospital discharge was less likely in obese children than normal weight children after cardiac arrest.[181]

The same study showed that obese children had significantly lower chance of ROSC than normal weight children (IHCA).[181]

Task Force Insights

The evidence identified was limited by conflicting results and differences in outcomes measured. The overall results do not suggest a requirement to deviate from standard CPR protocols.

Good Practice Statement (2025)

Standard CPR protocols should be used in obese patients (good practice statement).

Knowledge Gaps

- Few studies of CPR in obese infants, children and adolescents
- A standardized definition of obese, or population specific definition of obese, for the purpose of resuscitation research
- More robust adjusted analyses of the impact of obesity on CPR outcomes
- The effect of obesity on CPR techniques, CPR quality, and time to and delivery of resuscitation interventions in both adults and children
- Whether the degree of obesity influences CPR performance, outcomes following CPR including health-related quality of life, or inclusion in CPR research
- The effect of patient obesity on CPR provider outcomes (physical exertion, manual handling, fatigue)

IHCA Due to Suspected Cardiac Shunt/Stent Obstruction (PLS 4030.25, SysRev 2025)

Rationale for Review

Aortopulmonary shunts and/or patent ductus arteriosus stents are important tools for the palliation of patients with congenital heart disease. Current therapies for acute shunt obstruction can include: (1) increasing the inspired oxygen concentration to maximize alveolar oxygenation; (2)

vasoactive agents to maximize shunt perfusion pressure; (3) anticoagulation with heparin to prevent clot propagation; (4) shunt intervention by catheterization or surgery; (5) stabilization with ECPR/ECMO, and/or (6) sternal re-opening to relieve shunt compression.[183-188]

The PLS Task Force prioritized this SysRev to define what specific interventions other than standard CPR may improve clinical outcomes in pediatric IHCA due to suspected aortopulmonary shunt/stent obstruction. The SysRev was registered before initiation (PROSPERO Registration CRD42017080475). The full CoSTR can be found on the ILCOR website.[189]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children in cardiac arrest in the in-hospital setting who have suspected aortopulmonary shunt/stent obstruction
- Intervention: Any intervention [administration of oxygen, vasoactive agents to increase shunt/stent perfusion pressure, ECPR, heparin, sternal opening, catheter-based intervention, surgical intervention] or a combination of these interventions
- Comparison: Standard resuscitation
- Outcomes: Any clinical outcome
- Time frame: Literature search included all years up to June 6, 2024

Consensus on Science

There were 15 articles screened in full text and none met criteria for inclusion.

Treatment Recommendations (2025)

There is insufficient evidence to make a treatment recommendation for infants and children in cardiac arrest in the in-hospital setting who have suspected aortopulmonary shunt/stent obstruction other than standard resuscitation.

Justification and Evidence-to-Decision Framework Highlights

No evidence was identified, and therefore no treatment recommendations other than following standard resuscitation recommendations could be made.

Knowledge Gaps

- There is an absence of RCTs or comparative studies focused on interventions for IHCA due to aortopulmonary shunt or stent obstruction.
- There is an absence of data on the effectiveness of individual interventions (eg, vasoactive agents, heparin) or their combinations in improving clinical outcomes.
- More data are needed on the benefit of using ECPR in patients with specific cardiac anatomies, like those with single ventricle physiology status post shunt or stent. Further research is required to determine its effectiveness and potential risks in these subgroups.
- Data are lacking on survival rates and neurological outcomes following cardiac arrest due to shunt obstruction in pediatric patients.
- More information is needed on the ideal timing and combination of therapies (eg, vasoactive agents, anticoagulation, surgical intervention).

Cardiac Arrest Due to Pulmonary Embolism (PLS 4160.10, SysRev 2025)

Rationale for Review

Pulmonary embolism (PE) is a rare and potentially treatable cause of cardiac arrest in children and adolescents. This question had not previously been examined for children and was prioritized for review by the PLS Task Force. The SysRev was registered before initiation (PROSPERO Registration CRD42024560884). The full CoSTR can be found on the ILCOR website.[190]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) who are in cardiac arrest due to confirmed or suspected PE in any setting
- Intervention: Any specific alteration in the treatment algorithm (eg, fibrinolysis, embolectomy, thrombectomy, with or without ECPR)
- Comparison: Standard CPR
- Outcomes: Any clinical outcome
- Time frame: All years to May 15, 2024

Consensus on Science

No pediatric studies were identified that directly compared standard cardiac arrest care with any specific alteration in the treatment algorithm due to confirmed or suspected PE.

Two small single-center case series described a total of 10 infants and children where individual or combined interventions (fibrinolysis, embolectomy, thrombectomy, with or without ECPR) were used in addition to standard care for cardiac arrest associated with confirmed or suspected pulmonary embolism.[191,192]

One single institution case series identified PE as the cause of IHCA in 5 (6.3%) of 79 children who received at least 5 minutes of CPR for an IHCA.[191] They were treated with thrombolysis (IV tissue plasminogen activator) in addition to standard CPR; 4 of 5 patients were successfully resuscitated and survived to hospital discharge. Three patients had intact neurological outcome.

A retrospective cohort study of pediatric PE outcomes and risk factors from 2 Canadian pediatric hospitals reported 170 children aged 18 years or younger with massive and sub-massive pulmonary embolism, 5 of whom suffered cardiac arrest.[192] Patients were treated with individual or combined interventions (embolectomy, thrombolysis, and catheter-directed thrombolysis) with or

without ECMO during or after cardiac arrest for PE in addition to the standard cardiac arrest algorithm. Five cases achieved ROSC and 4 survived to hospital discharge.

Treatment Recommendations (2025)

There is insufficient evidence to make a treatment recommendation for or against the use of any specific alteration to the cardiac arrest algorithm for pediatric cardiac arrest due to suspected or confirmed PE.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

The task force considered additional data that did not meet the SysRev inclusion criteria. A single-center retrospective study of 33 children with massive and sub-massive PE reported 4 patients who sustained cardiac arrest. One patient died despite standard cardiac arrest care, while 1 of the 3 who were also treated with one of (or a combination of) systemic fibrinolysis, catheter-directed fibrinolysis, embolectomy or ECMO survived.[193] In 15 pediatric case reports that did not meet the SysRev inclusion criteria, 4 patients treated using a standard cardiac arrest algorithm did not survive. Seven of the 11 patients treated with alterations to the algorithm (fibrinolysis, embolectomy, ECMO) survived to hospital discharge.

Knowledge Gaps

- Effectiveness of fibrinolysis, embolectomy, thrombectomy with or without ECMO in children who had an in-hospital cardiac arrest due to apparent or confirmed PE

Pharmacological Interventions for the Treatment of Hyperkalemia in Children with Cardiac Arrest (PLS 4160.17, SysRev 2025)

Rationale for Review

Hyperkalemia is a potentially reversible cause of cardiac arrest in both adults and children. Although alternative approaches to advanced life support in patients with hyperkalemia-caused cardiac arrest are recommended by resuscitation councils,[6,194-196] this topic has never been formally reviewed by ILCOR. The SysRev was initiated as nodal between ALS and PLS Task Forces.[197] The SysRev was registered before initiation (PROSPERO Registration CRD42023440553). The full CoSTR can be found on the ILCOR website.[198]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Adults and children with hyperkalemia in any setting (both with or without cardiac arrest)
- Intervention: Acute pharmacological intervention with the aim of mitigating the harmful effect of hyperkalemia or with the aim of lowering potassium values
- Comparators: No intervention, a different intervention (including a different dose), or placebo
- Outcomes:
  - Critical: survival/survival with a favorable neurological outcome (at hospital discharge, 28 days, 30 days,1 month); survival/survival with a favorable neurological outcome at later times (>90 days); health-related quality of life.
  - Important: change in potassium; use of dialysis; electrocardiographic changes/arrythmias; cost-effectiveness
- Time frame: All years to September 9, 2024

Consensus on Science

The evidence in children in summarized here. For the results in adults, see the ALS CoSTR[199] and the SysRev.[197]

Change in Potassium Values (Nonarrest)

Five neonatal studies, 4 interventional and 1 observational, tested insulin and glucose using a weight-based approach.[200-204] Two studies reported decrease in potassium while 2 reported no change. The studies could not be pooled due to differences in methodology.

Four studies in neonates and children (53 patients) compared intravenous beta2-agonists (4-5 ug/kg) with no treatment for acute hyperkalemia. Meta-analysis showed a mean decrease in potassium of 1.0 mmol (95%CI: 1.5 lower to 0.6 lower) (follow-up range 60 mins).[205-208] Only 1 pediatric study investigated combination therapy of intravenous beta-agonists and insulin with glucose which showed a reduction in potassium level from a mean (SD) 6.8mmol (0.6) to 5.0 (1.2) after 45 minutes with the intervention.[209]

Inhaled beta2-agonists (400 ug salbutamol as inhalation) were compared with no treatment for acute hyperkalemia in 3 studies in neonates (51 patients in total), and meta-analysis showed a mean decrease in potassium of 0.9 mmol (95%CI: 1.2 lower to 0.5 lower) in the treatment group (follow up range 240 mins).[201,204,210]

No studies were found for the use of sodium bicarbonate for hyperkalemia in cardiac arrest in children.

Outcomes in Cardiac Arrest

Two observational studies investigated the treatment of hyperkalemia during cardiac arrest. Both studies investigated the use of calcium; 1 retrospectively in adult patients[211] and 1 as a secondary analysis of a prospective study (ICU-RESUSCITATION project) in infants and children.[172] The adult study found a lower unadjusted rate of ROSC with the administration of calcium, sodium bicarbonate,

or the combination.[211] In the pediatric study, calcium was frequently used during cardiac arrest and was associated with worse outcomes.[172] Both studies were assessed as high risk of bias.

Treatment Recommendations (2025)

For children in cardiac arrest associated with hyperkalemia, there is insufficient evidence to make a treatment recommendation for or against the use of calcium.

For children in cardiac arrest associated with hyperkalemia, there is insufficient evidence to make a treatment recommendation for or against the use of sodium bicarbonate.

We suggest using intravenous salbutamol or insulin with glucose (or a combination of both) in children with cardiac arrest associated with hyperkalemia with the aim to lower the potassium values during concurrently ongoing high-quality resuscitation efforts (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

Based on the current systematic review, there is evidence that treatment with insulin and glucose or inhaled or IV beta 2-agonists causes an acute reduction in potassium levels. For all interventions, the reduction in potassium was consistently in the range of 0.7 to 1.2 mmol/L. Whether this acute decrease in potassium translates to an improvement in clinical outcomes is unclear.

The rationale for administering calcium during cardiac arrest caused by hyperkalemia is based on the presumed ability to prevent arrhythmias. Although calcium is widely recognized and used for this indication, the current review did not find any clinical evidence to support this.

After discussion, the PLS Task Force decided not to make any statements about the treatment of children not in cardiac arrest, although some evidence for this group of patients exists and is summarized above.

There is no evidence for the use of bicarbonate to manage hyperkalemia in children. In adults, bicarbonate did not lower potassium values or improve outcomes.

The very low–certainty evidence suggests an association of calcium with worse outcomes but there are critical risks of bias and high uncertainty mainly due to resuscitation time (duration of resuscitative efforts) bias. The rationale for use of calcium for assumed myocardial protective effect is being questioned.

The effects of salbutamol and insulin with glucose on potassium values in cardiac arrest patients have not been studied. However, the task force agreed that the potential benefits of these pharmacological interventions outweigh potential risks, and their use is therefore justified.

Knowledge Gaps

- Optimal strategies for reducing potassium values in children in cardiac arrest associated with hyperkalemia
- Whether any decrease in potassium values (in both intra-arrest and peri-arrest patients) translates into meaningful patient-centered outcomes such as survival to discharge or survival with favorable neurological outcomes
- The role of calcium, if any, in protecting myocardial cells from hyperkalemia
- Management of children at high risk of hyperkalemia (eg, children with acute or chronic renal failure, tumor lysis syndrome, or others), particularly regarding the preferred treatment, appropriate dosing, and timing of interventions

INTRA-ARREST: ECPR

ECPR in Children With Single Ventricle Physiology (PLS 4030.09, 4030.10, SysRev 2025)

Rationale for Review

The risk of cardiac arrest in a child with single ventricle (SV) physiology is elevated.[212] Conventional CPR may not provide adequate reperfusion in this physiology and low likelihood of ROSC.[213] There is currently no specific recommendation for ECPR that delineates children with SV

physiology with IHCA refractory to conventional CPR. A new SysRev was registered before initiation (PROSPERO Registration CRD42023479671). The full CoSTR can be found on the ILCOR website.[214]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants, children, and adolescents with cardiac arrest following Stage I (Norwood/Hybrid), Stage II (Hemi-Fontan/Bidirectional Glenn) or Stage III (Fontan) palliation for congenital heart disease with SV physiology in the hospital setting
- Intervention: ECPR including ECMO or cardiopulmonary bypass during resuscitation of cardiac arrest
- Comparators: Conventional or manual CPR
- Outcomes: Critical: survival to hospital discharge; survival with favorable neurologic outcome. Important: decannulation from ECMO
- Time frame: All years to October 2023

Consensus on Science

Sixteen observational studies were included [215-220] all with very low–certainty evidence. No studies compared children with SV physiology who received ECPR with those receiving conventional or manual CPR. Five studies compared children with SV physiology who received ECPR with those receiving ECMO without ECPR (ECMO non-ECPR).[217,218,221-223].

An additional 11 studies described ECPR in SV patients, but with no comparator group.[187,215,216,219,220,224-229]. Of these, 8 studies were single-center observational cohorts with a total of 318 SV ECPR patients with a survival to hospital discharge rate ranging from 32-62%.[215,220,224-229]. The remaining 3 studies were registry cohorts from the Extracorporeal Life Support Organization with a total of 805 SV ECPR patients with a survival to hospital discharge rate ranging from 32-34%. [187,216,219]

No studies were identified comparing ECPR with conventional or manual CPR.

ECPR Versus ECMO Non-ECPR

For the critical outcome of survival to hospital discharge we identified 3 observational studies[217,218,223] with 91 pediatric SV patients (pooled OR 0.445, 95%CI 0.193-1.024) and 2 registry studies [222,228] (OR 1.09, 95%CI 0.71-1.71 and OR 0.665, 95%CI 0.26- 1.72). Collectively these studies found no significant difference in survival to hospital discharge with ECPR compared with ECMO non-ECPR in pediatric SV patients.

For the important outcome of decannulation from ECMO, 1 observational study of 40 pediatric SV patients (OR 1.75, 95%CI 0.50-6.09) found no difference in decannulation from ECMO with ECPR compared with ECMO non-ECPR.[229]

Subgroup Analyses

Two observational studies[218,222] in pediatric SV patients status post Stage I Norwood palliation found no difference in survival to hospital discharge with ECPR compared to ECMO non-ECPR (OR 1.09, 95% CI 0.71 -1.71 and OR 0.52, 95% CI 0.10-2.54).

One observational study in pediatric SV patients post Stage III Fontan palliation found no difference in survival to hospital discharge with ECPR compared with ECMO non-ECPR (OR 0.66, 95% CI 0.26 -1.72).[221]

There were no studies identified in SV patients' status post Stage II Hemi-Fontan/Bidirectional Glenn palliation comparing ECPR to ECMO non-ECPR.

Treatment Recommendations (2025)

There is insufficient evidence to make a treatment recommendation for or against the use of ECPR during cardiac arrest in children with single ventricle physiology**.**

There is insufficient evidence to make a treatment recommendation for or against the use of ECPR compared with ECMO non-ECPR in children with single ventricle physiology.

Justification and Evidence-to-Decision Framework Highlights

There is no published evidence in pediatrics that enables us to compare ECPR with conventional CPR. The available evidence suggests that when comparing ECPR with ECMO non-ECPR in a child with SV physiology the risk of survival to hospital discharge is not statistically different in ECPR compared with ECMO non-ECPR.

Knowledge Gaps

- Comparative prospective studies or randomized trials of ECPR versus conventional or manual CPR
- Few data on survival with neurologic outcome following cardiac arrest with ECPR
- Outcomes of subgroups of SV patients before Stage I, and after Stage I, II and III single ventricle palliation who undergo ECPR
- How the transition from conventional CPR to ECPR alters the quality of resuscitation measures
- How best to provide closed chest CPR and transition to a sternal opening for ECPR cannulation or how to perform open chest CPR in the context of cannulating to central ECPR
- Whether oxygenation targets in conventional CPR and at the transition to ECPR in cardiac patients who have cyanotic heart disease should be aligned with baseline pre-arrest blood oxygen saturations
- Whether there is a circuit prime and transfusion management strategy at the time of ECPR that is optimal
- How best to provide early post cardiac arrest care with ECPR (oxygenation, decarboxylation, perfusion pressure)
- Whether hypothermic temperature control should be delivered with ECPR

ECPR for Cardiac Arrest (PLS 4160.02, SysRev 2023, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) with in-hospital or out-of-hospital cardiac arrest
- Intervention: ECPR, including extracorporeal membrane oxygenation or cardiopulmonary bypass during resuscitation of cardiac arrest
- Comparators: Conventional or manual CPR without ECPR
- Outcomes: Any clinical outcome
- Time frame: June 2022 to October 1, 2024

Summary of Evidence

A SysRev was last conducted on this topic for the 2023 CoSTR summary.[124,125] This EvUp identified 4 systematic reviews[230-233], 1 narrative review,[234] and 21 other manuscripts[235-254] studying ECPR in the context of pediatric cardiac arrest; the great majority in children with cardiac disease and ICU cardiac arrest. Notably, 2 publications studied non-cardiac disease,[236,246] and 2 publications examined pediatric OHCA from the Extracorporeal Life Support Organization registry.[237,248] The complete EvUp is provided in Appendix B. Given the emerging evidence in noncardiac populations with IHCA and OHCA, it may be reasonable to consider a ScopRev in non-cardiac populations in the next 2 years.

Treatment Recommendation (2023)

We suggest that ECPR may be considered as an intervention for selected infants and children (eg, pediatric cardiac populations) with IHCA refractory to conventional CPR in settings where resuscitation systems allow ECPR to be well performed and implemented (weak recommendation, very low–certainty evidence).[124,125]

There is insufficient evidence in pediatric OHCA to formulate a treatment recommendation for the use of ECPR.

POSTRESUSCITATION

Blood Pressure Targets Following Return of Circulation After Pediatric Cardiac Arrest (PLS 4190.01, SysRev 2025)

Rationale for Review

Optimal BP targets in infants and children following return of circulation after cardiac arrest are not well defined. New evidence emerged after the ILCOR 2024 SysRev,[73,74] prompting an updated systematic review this year. The SysRev was registered before initiation (PROSPERO Registration CRD42023483865). The full CoSTR can be found on the ILCOR website.[255]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children in any setting (in-hospital or out-of-hospital cardiac arrest) after ROSC or return of circulation (ROC)
- Intervention: A specific blood pressure target
- Comparators: No blood pressure target or a different blood pressure target
- Outcomes: Critical: survival to hospital discharge; survival with favorable neurological outcome
- Time frame: August 2023 to April 3, 2024

Consensus on Science

Seven nonrandomized observational cohort studies were included, 5 of which were secondary analyses.[256-262] BP target definitions (eg, systolic, mean and diastolic BP; and >5th, >10th and >50th centile for age) and time frames for measurement (<20 minutes, 0 to 6 hours, within 24 hours, and within 0–72 hours) varied across studies. Two studies were excluded as the definition of hypotension

could not be ascertained.[263,264] Additional unpublished data was provided by 2 authors, [256,262] which enabled meta-analysis including these studies.

The overall certainty of evidence was rated as very low for all outcomes, downgraded for very serious risk of imprecision, indirectness, inconsistency, and study design.

BP cut-offs of systolic BP (5th and 10th percentile) and mean arterial pressure (5th, 10th and 25th percentiles) for 0-6 hours after return of circulation were analyzed for both survival to hospital discharge and survival with favorable neurological outcomes. The results are summarized in Table 6.

Table 6. Summative Results of Studies for Post-Arrest BP Targets review

Outcomes (Importance)	Study type, No. participants (n)	Certainty of Evidence (GRADE)	aRR (95% CI)	ARD with Intervention
≤5th centile versus > 5th centile for age systolic BP within 6 hours post ROC				
Survival to hospital discharge (critical)	Non-randomized, n=931[257-260]	Very low	1.41; (95%CI, 1.20 to 1.60)	173 more patients/1000 [95% CI, 84 more patients/1000 to 253 more patients/1000] survived with the intervention
Favorable neurologic outcome at hospital discharge (critical)	Non-randomized, n=1371[257,258,262]	Very low	1.30; (95%CI, 1.06 to 1.60)	132 more patients/1000 [95% CI, 26 more to 264 more patients/1000] survived with favorable neurologic outcome with the intervention
≤10th centile versus > 10th centile for age systolic BP within 6 hours post ROC				
Survival to hospital discharge (critical)	Non-randomized, n=693[256]	Very Low	1.21; (95%CI, 1.10 to 1.33); P <0.01	138 more patients/1000 [95% CI, 66 more patients/1000 to 219 more patients/1000] survived with the intervention
Favorable neurologic outcome at hospital discharge (critical)	Non-randomized, n=1480[256,262]	Low	1.22; (95%CI, 1.10 to 1.35); P <0.01	116 more patients/1000 [95% CI, 53 more patients/1000 to 185 more patients/1000] survived with favorable neurologic outcome with the intervention
≤5th centile versus >5th centile for age mean arterial BP within 6 hours post ROC				
Favorable neurologic outcome at hospital discharge (critical)	Non-randomized, n=787[262]	Low	1.36; (95%CI, 1.18 to 1.58); P <0.01	158 more patients/1000 [95% CI, 79 more patients/1000 to 254 more patients/1000] survived with favorable neurologic outcome with the intervention
≤10th centile versus >10th centile for age mean arterial BP within 6 hours post ROC				

Outcomes (Importance)	Study type, No. participants (n)	Certainty of Evidence (GRADE)	aRR (95% CI)	ARD with Intervention
Favorable neurologic outcome at hospital discharge (critical)	Non-randomized, n=787[262]	Low	1.21 (95%CI, 1.05 to 1.32); P<0.01	102 more patients/1000 [95% CI, 24 more patients/1000 to 156 more patients/1000] survived with favorable neurologic outcomes with the intervention
≤25th centile versus >25th centile for age mean arterial BP within 6 hours post ROC				
Favorable neurologic outcome at hospital discharge (critical)	Non-randomized, n=787[262]	Low	1.29 (95%CI, 0.96-1.74)	150 more patients/1000 [95% CI, 21 fewer patients/1000 to 382 more patients/1000] survived with favorable neurologic outcome with the intervention

ARD indicates absolute risk difference; aRR, adjusted risk reduction; CI, confidence interval; GRADE, Grading of Recommendations, Assessment, Development, and Evaluation; and ROC, return of circulation.

Prior Treatment Recommendations (2024)

We suggest in infants and children with return of circulation after an IHCA or OHCA that a systolic BP >10th percentile for age should be targeted (weak recommendation, very low–certainty evidence). [73,74]

Treatment Recommendations (2025)

We suggest in infants and children post return of circulation, following an in-hospital or out-of-hospital cardiac arrest, that a systolic or mean arterial pressure blood pressure >10th percentile for age should be targeted (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

Measurement of BP is a low-cost intervention and available in nearly all resource settings. However, the Task Force did not review the cost-effectiveness of intermittent, non-invasive BP measurement compared with invasive arterial or continuous BP measurement.

There were no RCTs comparing different treatment approaches or BP targets following cardiac arrest. The available evidence consisted of observational data demonstrating the impact of exposure to different BP thresholds on clinically important outcomes. However, the BP thresholds were chosen either a-priori by investigators as a clinically important threshold (eg, ≤5th percentile) or the cut off value was derived statistically from the population data as the most significant inflection point (≤10th percentile). The task force focused on the impact of hypotension on clinical outcomes.

The PLS Task Force considered the exposure overlap of the 2 thresholds of systolic blood pressure <5th centile and <10th centile. It was not statistically possible to perform meta-regression to compare the 2 treatment targets. The consensus was that the higher threshold cut off target (<10th centile) included the population included in the <5th centile group. Acknowledging the low certainty of evidence, the target of >10th centile systolic BP was the more acceptable systolic BP goal and ensured avoidance of the 5th to 10th BP centiles that were associated with worse outcome in the larger study.[256]

Although the effect size from the pooled studies is small, the value of the outcome is high and the potential impact on infants and child survivors globally is therefore large.

Knowledge Gaps

- Interventional randomized controlled trials comparing benefit or harm of targeting specific BP targets
- Information on impact of pre-hospital BP measurement or treatment for OHCA
- Whether specific sub-groups (eg, medical or cardiac surgical patients) post return of circulation require different BP targets (systolic, mean arterial pressure, or diastolic)
- Data to demonstrate a causal relationship between treatment interventions to achieve higher BP targets and improved outcomes

- The optimal strategy to achieve a BP above the threshold level and any harm associated with these interventions
- Optimal BP targets during extracorporeal life support post-cardiac arrest or when cerebral autoregulation is impaired

Prediction of Survival With Poor Neurological Outcome After Return of Circulation Following Pediatric Cardiac Arrest—Combined Prognostic SysRev (PLS 4220.01, 4220.02, 4220.03, 4220.04, SysRev 2025)

Rationale for Review

The PLS Task Force undertook a SysRev considering the use of individual prognostic tests including clinical signs, blood biomarkers, brain electrophysiology, and brain imaging to predict poor neurological outcome (PROSPERO Registration CRD42021279221). This is the second part of a SysRev following the original review of individual prognostic tests for predicting good neurological outcome[265] published in the 2023 CoSTR summary).[124,125] The full CoSTRs can be found on the ILCOR website.[266-269]

We defined poor neurological outcome prediction as imprecise when the false positive rate (FPR) was >1%. We defined the evidence as reliable if the FPR was <1% (with upper 95% CIs <10%) and moderately reliable if FPR was <1% (without a restriction on width of 95% CI). A low FPR rate means that few patients who are predicted to have poor outcome will in fact have a favorable outcome. The task force considered that for prediction of poor outcome, a low FPR (eg, <1%) is more desirable than a high sensitivity. The cut-off of FPR<1% (equivalent to 99% specificity) was chosen as the consequences of false pessimism are substantial and may result in discontinuation of life-sustaining therapy in patients who would have had a good outcome.

Except where noted, all PICOST questions for neuroprognostication used the same population, comparator, outcome, study design, and time frame. The timing of the intervention/diagnostic test was

also the same for each. These parameters are therefore listed here once and not repeated in subsequent sections. For all topics, the available evidence had a high risk of bias based on heterogeneity across studies, few studies/patients included, lack of blinding, variation in test assessment and performance, and variability in outcome measurement. Therefore, no meta-analysis was performed, and evidence is considered very low certainty. Overall assessment of test performance was based on visual assessment of forest plots. If only 1 study was available (with small patient sample size), then a suggestion or recommendation could not be made.

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Children (<18 years) who achieve spontaneous or mechanical ROC after resuscitation from (IHCA and OHCA.
- Intervention: Index prognostic tests, recorded at < 12 hours, 12-24 hours, 24-48 hours, 48-72 hours, 72 hours to 7 days, and/or 7-10 days after cardiac arrest
- Comparators: There was no control group for intervention/exposure. The accuracy of the prognostic index test was assessed by comparing the predicted outcome with the final outcome, which represents the comparator.
- Outcomes:
  - Critical: survival with poor neurological outcome defined as a Pediatric Cerebral Performance Category score of >3, or Vineland Adaptive Behavioral Scale-II <70. Pediatric Cerebral Performance Category score ranges 1 (normal), 2 (mild disability), 3 (moderate disability), 4 (severe disability), 5 (coma), and 6 (brain death)
  - Important: poor neurological outcomes measured with other assessment tools; Pediatric Cerebral Performance Category score >2; change in Pediatric Cerebral Performance Category score >2 from baseline
- Time frame: All years up to August 24, 2024

Blood Biomarkers for the Prediction of Poor Neurological Outcome After ROC Following Pediatric Cardiac Arrest (PLS 4220.01, SysRev 2025)

Intervention

Blood biomarkers, including serum biomarkers either specific to central nervous system damage, eg, neuro-specific enolase (NSE), S100 calcium-binding protein B (S100b), glial fibrillary acidic protein, neurofilament light chain (NfL), or blood markers of inflammation or systemic ischemic reperfusion (eg, blood pH or lactate).

Consensus on Science

Blood biomarker accuracy is summarized in Table 7. Lactate was evaluated in 6 studies.[270-275] Only 2 of the 6 identified an FPR <1% for poor outcome prediction.[270,275] Persistent acidosis (pH <7.0) had a FPR for poor outcome prediction of 5-20% and low sensitivity in 4 studies.[270,273-275] pH and lactate were not reliable prognostic tests.

Three studies reported NSE and S100b in 156 children.[275-277] At 24 hours, S100b predicted a poor neurological outcome with a FPR of 0% (95% CI 0-20%) and a sensitivity of 29-38%.[275-277] Similarly, NSE predicted a poor neurological outcome with a FPR of 0% (95% CI 0-20%) and a sensitivity of 19-26%.[275-277] Myeline basic protein was assessed in 1 study at 24 and 48 hours, predicting poor neurological outcome with low FPR 0% (95%CI 0-20%).[277] NSE, S100b and myeline basic protein all fulfilled reliable test criteria but with a wide range of cutoff thresholds in the individual studies.

Only 1 study reported ubiquitin C-terminal hydrolase L1 (UCH-L1), NfL, tubulin associated unit (Tau), and glial fibrillary acidic protein biomarker prediction of poor neurological outcome at 24, 48, and 72 hours.[278] These tests did not reach pre-specified reliability thresholds.

Table 7. Blood Biomarker Test for Poor Neurological Outcome Prediction Accuracy

Category	Study Count	Patients n=	Threshold and Time scale	False Positive Rate (estimate or range)[95%CI]	Sensitivity
Lactate	1[275]	94	>28.8 mmol/L at <1 hr	<1% [0-8%]	11%
Lactate	1[270]	61	>2mmol/L by 48 hr	<1% [0-11%]	23%
Lactate	4[270,272-274]	780	>2mmol/L at 6, 12, 24, and 48hrs	14-84%	32-94%
Lactate	1[271]	120	>5mmol/L at 24 hr	11% [5-19%]	83%
NSE	3[275-277]	152	53.1 µg/L, 56 µg/L 7 and 132.7 µg/L at <1 hr or 24 hr	0% [0-20%]	19-26%
S100b	3[275-277]	156	0.128 µg/L, 2.0 µg/L and 2.24 µg/L at <1 hr or 24 hr	0% [0-20%]	29-38%
MBP	1[277]	43	5.83 µg/L at <1 hr or 24 hr	0% [0-20%]	4-12%
UCH-L1, NfL, Tau and GFAP	1[278]	117	Variable *best* thresholds at 24, 48 or 72 hr	4-5%	12-61%

GFAP indicates glial fibrillary acidic protein; MBP, myelin basic protein; NfL, neurofilament light chain; NSE, neuron-specific enolase; S100b, S100 calcium binding protein B; Tau, tau protein; and UCH-L1, ubiquitin carboxy-terminal hydrolase L1.

Treatment Recommendations (2025)

We recommend that no single blood-based biomarker be used in isolation to predict poor neurological outcome in children after cardiac arrest (strong recommendation, very low–certainty evidence).

Clinicians should use multiple tests in combination for poor neurological outcome prediction (good practice statement).

We suggest against using lactate and pH after return of circulation for predicting poor neurological outcome in children after cardiac arrest at any time point (weak recommendation, very low–certainty evidence).

There is insufficient evidence to make a recommendation for or against the use of other blood-based biomarkers (eg, S100beta, neuron specific enolase, neurofilament light chain etc.) after return of circulation for predicting poor neurological outcome in children after cardiac arrest at any time point.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

Included studies were observational studies and RCTs, but not primarily designed to test prognosis of blood biomarkers.

Lactate and pH were nonspecific markers of hypoxia-ischemia following cardiac arrest. Extreme values (very high lactate, very low pH) have a low FPR in the included studies, but frequent outliers and very low sensitivity were reported.

Four studies identified threshold values across a range of blood-based biomarkers (S100b, NSE, myeline basic protein, UCH-L1, NfL, Tau, and glial fibrillary acidic protein) that are known to represent brain injury and are associated with poor neurological outcome with a low FPR. However, sensitivity was low and the wide range of reported thresholds preclude any accurate description of clinical utility. Furthermore, they are not widely available for clinical use, even though they only require the patient's blood.

No studies reported any assessment of the confounding influence of medication. None of the included studies specifically excluded the presence of residual sedation at the time clinical examination was assessed.

Lack of blinding is a major limitation of biomarker tests, even if the withdrawal of life-sustaining therapy based on test results has not been documented in any of the studies included in our review. No studies included blinding of clinicians to test results and only 1 study had blinded outcome assessment.

Knowledge Gaps

- The prognostic value of potential candidate biomarkers that are more specific for neurological injury (eg, NSE, S100b, NfL, glial fibrillary acidic protein, Tau, UCH-L1)
- Economic cost evaluation and cost-effectiveness of biomarker testing
- Optimal multi-modal prognostication, including timing, definitions of testing, accurate outcome timing, and outcome definition

- Wider research and consultation with patients, children, parents, guardians and caregivers, health care professionals, and members of the wider society on understanding survivorship after pediatric cardiac arrest to inform correct definitions and framework of neurological outcome for prediction research

Clinical Examination for the Prediction of Poor Neurological Outcome After Return of Circulation Following Pediatric Cardiac Arrest (PLS 4220.02, SysRev 2025)

Intervention: Clinical Examination

Including every part of a bedside neurological clinical examination, including pupillary response (assessed using manual light reflex or automated pupillometry), conscious level (eg, Glasgow Coma Scale [GCS] score or Full Outline of Unresponsiveness score), and brainstem reflexes.

Summary results of clinical examination tests and predictive accuracy are in Table 8.

Absence of the pupillary light reflex prior to 24 hours was not a reliable prognostic test. At 48 and 72 hours after ROC, FPR was less than 1% but 95% confidence intervals were wide.[277,279-283], [277,279,284] No studies evaluated information from automated pupillometry.

Total GCS[282] and GCS motor score of less than 4[279, 294, 296] as assessments of level of consciousness were not predictive of poor neurological outcome. GCS was an unreliable test and motor response was moderately reliable in only 1 study at 72 hours.[279] Presence of other brainstem reflexes (pain, gag reflex, and cough reflex) were infrequently reported and unreliable.[285], [284], [283]

Table 8. Clinical Examination Test Accuracy for Poor Neurological Outcome Prediction

Test Domain	No. of Studies	Patients n=	Time Scale	False Positive Rate (estimate or range)[95%CI]	Sensitivity (range) or [95%CI]
Pupil Reactivity	7[277,279-283]	312	<1 hour to 24 hours	10-60%	33-84%
Pupil Reactivity	3[277,279,284]	139	48 and 72 hours	<1% [0-40%]	12-46%
GCS motor score <4	3[279, 294, 296]	252	<1 hour and at 4 to 6 hours	50-83%	86-94%
GCS < 7	1[282]	152	24 hours	69% [41-89%]	94% [73-100%]
Motor Response	1[279]	27	48 hours	20% [1-72%]	73% [50-89%]
Motor Response	1[279]	29	72 hours	<1% [0-28%]	61% [36-83%]

Test Domain	No. of Studies	Patients n=	Time Scale	False Positive Rate (estimate or range)[95%CI]	Sensitivity (range) or [95%CI]
Pain response	1[285]	41	6 to 12 hours	0% [0-15%]	33% [13-59%]
Cough or Gag response	2[283]	153	24 hours	60% [36-81%]	65-68%
Pain response	1[284]	20	72 hours	8% [0-38%]	75 [35-97%]

GCS indicates Glasgow coma scale.

Prior Treatment Recommendations (2015)

We suggest that practitioners use multiple variables when attempting to predict outcomes for infants and children after cardiac arrest (weak recommendation, very low–quality evidence).

No previous recommendation regarding use of clinical exam.

Treatment Recommendations (2025)

We recommend that no single clinical examination test be used in isolation to predict poor neurological outcome in children after cardiac arrest (strong recommendation, very low–certainty evidence).

Clinicians should use multiple tests in combination for poor neurological outcome prediction (good practice statement).

The absence of pupil reactivity to light at 48 and 72 hours after ROC may be considered as part of multi-modal testing to predict poor neurological outcome in children after cardiac arrest (good practice statement).

We suggest against using absence of pupil reactivity to light within 24 hours after ROC to predict poor neurological outcome in children after cardiac arrest (weak recommendation, low-certainty evidence).

We suggest against using GCS within 24 hours after ROC to predict poor neurological outcome in children after cardiac arrest (weak recommendation, low-certainty evidence).

There is insufficient evidence to make a recommendation for or against the use of other brainstem or motor response tests to predict poor neurological outcome in children after cardiac arrest at any time point.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

For total GCS, GCS motor score and overall motor response, and brain stem tests, only 1 study was available (with small patient sample size) for each test and time point and therefore a suggestion or recommendation could not be made.

For all clinical examination modalities, the inaccuracy of outcome prediction tests may be due to confounding from the effect of sedatives used for delivery of neuroprotective interventions (eg, hypothermic temperature control) or to facilitate ventilation.

No studies reported any assessment of the confounding influence of medication.

No studies included blinding of test results from treating clinicians and only 1 study had blinded outcome assessment (for pupil light reactivity). Lack of blinding is a major limitation of clinical examination tests studies.

The studies inconsistently reported the co-intervention of temperature control on the clinical assessments that will be affected by hypothermia.

Despite its limitations, given the ease of conducting a bedside assessment, the balance between the costs and benefits favors benefits for the functional assessment of pupil light reactivity and coma.

Knowledge Gaps

- Clinical examination for prognostication after cardiac arrest appears promising, but more research is required in infants and children.
- The impact of residual medication or temperature on pupillary light reflex assessment, coma score and motor response in infants and children

- Costs and benefits of the use of automated pupillometry compared with simple pupillary light reflex assessment
- Economic cost and cost-effectiveness of clinical examination for prognostication of poor neurologic outcome
- Optimal approach to prognostication using multi-modal approaches, timing, definitions of testing, accurate outcome timing and outcome definition
- We encourage wider research and consultation with patients, children, parents, guardians and caregivers, health care professionals and members of the wider society on understanding survivorship after pediatric cardiac arrest to inform correct definitions and framework of good neurological outcome for prediction research.

Electrophysiology Testing for the Prediction of Poor Neurological Outcome After ROC Following Pediatric Cardiac Arrest (PLS 4220.03, SysRev 2025)

Intervention: Electrophysiology Testing

Including surface bioelectrical recordings from the central nervous system such as electroencephalogram (EEG) and evoked potentials (EPs) (eg, brainstem auditory evoked potentials, and short-latency somatosensory evoked potentials [SSEPs]). We included studies of the interpretation of raw signals or summary measures derived from processed EEG signals such as amplitude-integrated EEG (aEEG), quantitative EEG (qEEG), or bispectral index.

Summary of electrophysiology tests, time scale and prediction accuracy are in Table 9.

Presence of clinical or electrographic seizures in children post-cardiac arrest as a prognostic test was unreliable.[272-274,280,285-294] Presence of status epilepticus at 4 to 72 hours predicted poor neurological outcome at ICU or hospital discharge, with a low FPR of 0-5% (upper limit of 95% CI ranged 13-41%)[284,287,292-294] and presence of myoclonic status epilepticus on EEG in 2 studies predicted with a FPR 0% (95% CI 0-34%).[285,291] Both were moderately reliable tests.

The absence of a benign continuous EEG background pattern was an inaccurate and unreliable method for predicting poor neurological outcome.[277,280,283-288,290-295] The presence of an attenuated, isoelectric, or flat EEG after 24 hours had improved prediction accuracy; however, it was imprecise (at the FPR<1% cut off) in more than 50% of included studies.[277,280,283-288,290-295] Presence of burst suppression, burst attenuation or generalized periodic epileptiform discharges after 24 to 72 hours had a FPR <1% (95%CI upper limit range 16-54%) in 3 of 4 studies and was moderately reliable.[284,285,294]

Absence of reactivity,[277,280,283-288,290-295] sleep II architecture or sleep spindles,[280,283] or variability on EEG[291,293] were unreliable tests for poor outcome prediction. A composite score assessing EEG background from a 24-hour monitoring period, obtained from quantitative EEG using the amplitude integrated EEG trace, was assessed in only 1 study and unreliable.[296]

SSEPs, evaluating bilateral absence of N20 waves, reported a FPR 0% (95% CI 0-52%) at 24 and 48 hours and 17% at 72 hours.[297] The test was moderately reliable to predict poor neurological outcome, but only assessed in 1 small study.

Table 9. Electrophysiology Tests Accuracy for Poor Neurological Outcome Prediction

Category	Study Count (ref)	Patients n=	Time scale	False Positive Rate (estimate or range)[95%CI]	Sensitivity
Presence of clinical or electrographic seizure	11[272-274,280,285-294]	1308	4-24 hr	0-20% (3/11 <1% [0-37%][287,290,291]	2-38%
Presence of clinical or electrographic seizure	10[272-274,280,285-294]	1053	48-72 hr	0-42% (3/10 <10%)[272,288,291]	0-58%
Presence of status epilepticus on EEG	5[284,287,292-294]	299	4-72 hr	0-5% [95% CI upper limit 13-41%]	9-25%
Presence of myoclonic status epilepticus on EEG	2[285,291]	61	48 hr	0% [95% CI 0-34%]	17-21%
Absence of continuous or normal background EEG*	14[277,280,283-288,290-295]	563	4-72 hr	0-91% (4/14 studies <10%)	7 to 96%
Presence of attenuated, isoelectric or flat EEG background	4[283,287,293,295]	341	<24 hr	10-90%	51-100%

Category	Study Count (ref)	Patients n=	Time scale	False Positive Rate (estimate or range)[95%CI]	Sensitivity
Presence of attenuated, isoelectric or flat EEG background	9[277,280,285,286,288,290-292,294,295]	526	24 hr to 6 days	0-71% (all) (7/9 <10% [95% CI upper limit 4-52%])[280,285,286,288,290,291] (4/9 <1% [95% CI upper limit 4-52][280,285,290,291]	17-100%
Presence of burst suppression, burst attenuation or GPEDS on EEG	7[283,285-287,291,293,294]	395	<24 hr	0-19% 4/7 <1% [95% CI upper limit 16-54%]	9-30%
Presence of burst suppression, burst attenuation or GPEDS on EEG	4[284,285,294]	98	hours	0-14% (all) (¾ studies[284,285,294] <1% [95% CI upper limit 16-54%])	0-67
Absence of reactivity	3[291,293,294]	222	6-72 hr	0-93%	36-100%
Absence of sleep II architecture	2[280,283]	123	6-24 hr	20-43%	84-92%
Absence of variability	2[291,293]	162	6-48 hr	0-80%	21-82%
Quantitative EEG scoring	1[296]	30	24 hr	6% [0-27%]	33%
Somatosensory evoked potential (SSEPs)**	1[297]	12	24 and 48 hr	0% [0-52%]	100% [29-100]
Somatosensory evoked potential (SSEPs)**	1[297]	12	72 hr	17% [0-64%]	100% [29-100]

*Defined as normal, continuous and reactive, continuous and unreactive, and nearly continuous by ACNS definitions[298]..
** Absence of N20 waves.
ACNS indicates American Clinical Neurophysiology Society; EEG, electroencephalogram; GPEDS, generalized periodic epileptiform discharges; and SSEP, somatosensory evoked potential.

Prior Treatment Recommendations (2015)

We suggest that the use of EEG within the first 7 days after pediatric cardiac arrest may assist in prognostication (weak recommendation, very low–quality evidence).

Treatment Recommendations (2025)

We recommend that no single electrophysiology test be used in isolation to predict poor neurological outcome in children after cardiac arrest at any time point (strong recommendation, very low–certainty evidence).

Clinicians should use multiple tests in combination for poor neurological outcome prediction (good practice statement).

The presence of status epilepticus between 24-72 hours after ROC, presence of burst suppression, burst attenuation or GPEDs between 24-72 hours after ROC, all had moderate reliability and may be considered as part of multi-modal testing to predict poor neurological outcome in children after cardiac arrest (good practice statement).

We suggest against using the following EEG features for predicting poor neurological outcome: presence of clinical or electrographic seizures; absence of sleep spindle and sleep II architecture on EEG, continuous or normal background EEG, EEG reactivity and EEG variability, at any time point (weak recommendation, very low–certainty evidence).

There was insufficient evidence to make a recommendation for or against the use of presence of attenuated, isoelectric, or flat EEG, absence of N20 response on SSEPs, presence of myoclonic status epilepticus, or quantitative EEG score to predict poor neurological outcome in children after cardiac arrest at any time point.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

The available scientific evidence had a high risk of bias based on high heterogeneity across studies, few studies and few patients included, lack of blinding, variation in test assessment and performance, and variability in outcome measurement. Overall assessment of test performance was based on visual assessment of forest plots.

Electrophysiology monitoring may enable reversible events (eg, seizures) to be identified, as well as providing prognostic information. Treatment of seizures may prevent additional secondary injury following a hypoxic-ischemic insult. The role of electrophysiology monitoring was not assessed for this purpose.

The complex interpretation of normality in background EEG patterns in preterm and term infants, and the impact of brain maturation on EEG patterns in infancy and childhood, requires expert neurophysiology input. Studies reported limited information on handling of this area and further refinement of definitions and application of recommendation are required.

SSEPs have high precision in adult studies of neuroprognostication in comatose patients after cardiac arrest.[299] The task force recognizes the lack of available data in children and strongly encourages further multicenter evaluation.

Knowledge Gaps

- Electrophysiology tests for prognostication after cardiac arrest appear promising but more research is required in infants and children.
- More research is required on type of monitoring, intermittent or continuous EEG, use of reduced channel monitoring, quantitative EEG systems, and duration and timing of prognostic assessment.
- Validation needed of ACNS[298] or other international definitions of EEG indices within the pediatric ICU environment for infants and children after cardiac arrest.
- Further work needed on multi-modal prognostication, timing, definitions of testing, accurate outcome timing and definition.
- We encourage wider research and consultation with patients, children, parents, guardians and caregivers, health care professionals and members of the wider society on understanding survivorship after pediatric cardiac arrest to inform correct definitions and framework of good neurological outcome for prediction research.

Brain Imaging for the Prediction of Poor Neurological Outcome After Return of Circulation Following Pediatric Cardiac Arrest (PLS 4220.04, SysRev 2025)

Intervention: Neuroimaging Modalities

These modalities include head computed tomography (CT) and brain magnetic resonance imaging (MRI).

Head CT reported absence of gray-white matter differentiation or reversal sign at 24 hours was a moderately reliable test for poor neurological outcome prediction.[294,300] All other CT reported tests (presence of effacement of sulci or basal cisterns, presence of CT lesions, oedema, or intracranial hemorrhage) were unreliable for poor neurological outcome prediction.[277,294,300]

MRI apparent diffusion coefficient threshold $<650x10^{-6}$ mm^2/s in ≥10% of brain volume (indicating high ischemic burden), at a median of 4 days after ROC, predicted poor neurological outcome with FPR 0-6% (95% 1-21%) and sensitivity of 49-52%.[286,288,301] One study reached threshold for moderate reliability.[301]

Any region of abnormality on restricted diffusion, or individual regions of diffusion restriction did not meet our threshold for reliability.[284,288], [284,301-303]

Table 10 summarizes results from CT and MRI imaging.

Table 10. Brain Imaging for the Prediction of Poor Neurological Outcome

Category	Study Count	Patients n=	Time Scale	False Positive Rate (estimate or range)[95% CI]	Sensitivity
Head CT Absence of GWM differentiation	2[294,300]	142	24 hr	0-36%	20 to 30%
Head CT Presence of reversal sign	1[300]	78	24 hr	0% [0-12%]	65%
Head CT Presence of effacement of sulci or basal cisterns	2[294,300]	142	24 hr	0-7 [95% CI upper limit 0-30%]	27-68%
Head CT Presence of CT lesions, oedema, or intracranial hemorrhage	3[277,294,300]	173	24 hr	7-17%	11 to 68%
Magnetic Resonance Imaging (MRI) ADC threshold <650x10-6 mm2/s in ≥10% of brain volume	3[286,288,301]	250	4-7 days	0-6% [1-21%]	49-52%

Category	Study Count	Patients n=	Time Scale	False Positive Rate (estimate or range)[95% CI]	Sensitivity
Magnetic Resonance Imaging (MRI) ADC threshold for high ischemic burden	1[301]	90	4-7 days	<1% [0-21%]	80% [44-97%]
Magnetic Resonance Imaging (MRI) Any region of abnormality on restricted diffusion	2 [284,288]	97	4-7 days	12% to 58%	98% to 100%
Magnetic Resonance Imaging (MRI) – 14 Individual regions of the brain on DWI, T1, T2 weighted imaging.	3[284,302,303]	67	4-7 days	0-33% [95% CI upper limit 23-60%]	0-57%

ADC: apparent diffusion coefficient; CT: computed tomography; DWI: diffusion-weighted imaging; GWM: gray-white matter; MRI: magnetic resonance imaging

Treatment Recommendations (2025)

We recommend no single imaging test be used alone to predict poor neurological outcome in children after cardiac arrest at any time point (strong recommendation, very low–certainty evidence).

Clinicians should use multiple tests in combination for poor neurological outcome prediction (good practice statement).

An abnormal MRI showing high ischemic burden on apparent diffusion coefficient mapping at 72 hours and beyond after ROC or CT scan showing loss of gray-white matter differentiation within 24 hours after ROC may be considered as part of multi-modal testing to predict poor neurological outcome in children after cardiac arrest (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision table is provided in Appendix A.

The available scientific evidence had a high risk of bias based on high heterogeneity across studies, few studies and few patients included, lack of blinding, variation in test assessment and performance, and variability in outcome measurement. Overall assessment of test performance was based on visual assessment of forest plots.

The low FPR (high specificity) for abnormal MRI on global assessment for predicting poor neurological outcome reduces the chance of false pessimism if an abnormal MRI predicts a poor

neurological outcome. FPR <1% was only recorded for 1 study for global assessment of brain injury. Low FPR was identified during regional brain assessment, however in only a few cases, and with wide confidence limits on the point estimate.

The sensitivity of abnormal MRI or CT to predict a poor neurological outcome is moderate to high, but up to 40% may be falsely categorized and a falsely pessimistic prediction made.

The precision of MRI and CT is affected by the timing of the investigation and is at risk of pseudo-normalization. The definition of a presence diffusion-weighted imaging or cut off values for apparent diffusion coefficient level on MRI, or gray-to-white matter ratio on CT was inconsistent in the included studies.

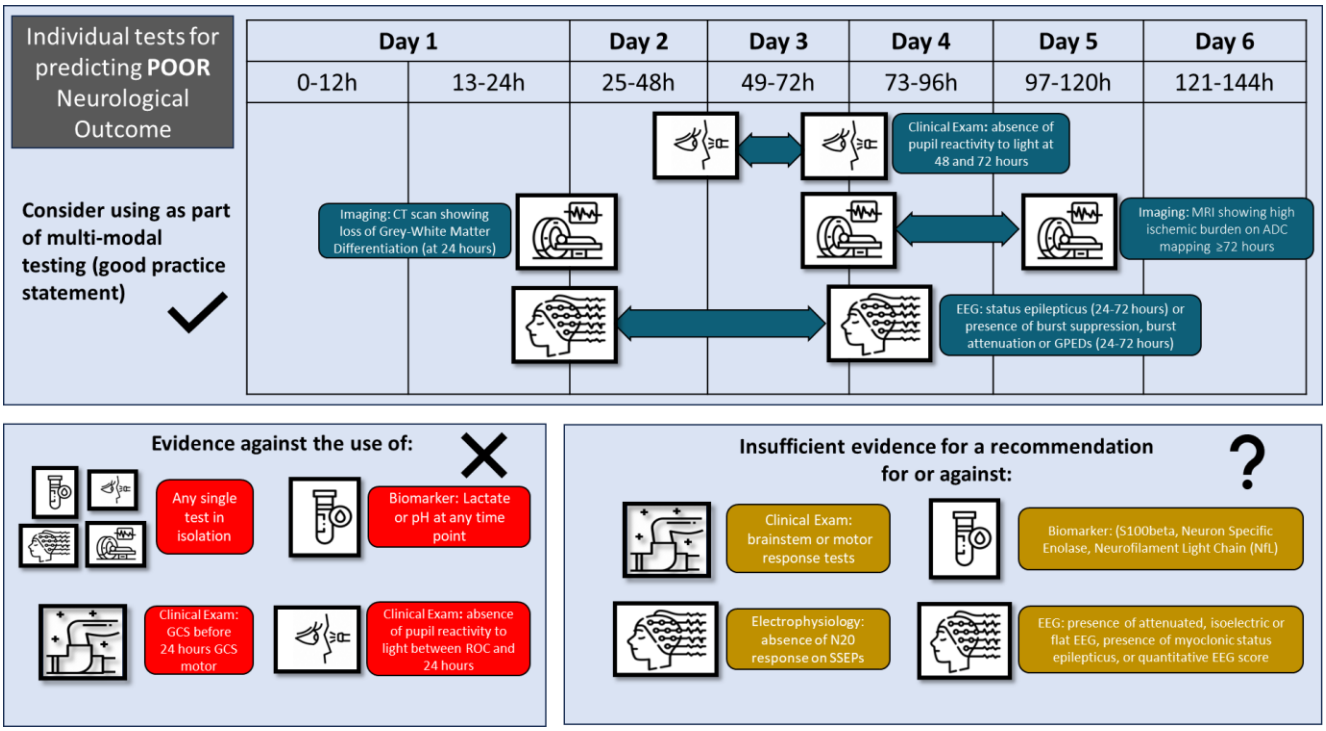
MRI and CT are both expensive tests and require specialist equipment, training, interpretation and most often, patient transport to obtain the information. This may be prohibitive in physiologically unstable patients, or some health care settings.

Task Force Knowledge Gaps

- Neuro-imaging for prognostication after cardiac arrest appears promising, but more research is required in infants and children.
- Standardization of definitions and assessment of optimal thresholds for gray-to-white matter ratio calculation on CT, and diffusion-weighted imaging, apparent diffusion coefficient thresholds on MRI
- The optimal timing for prognostication using CT and MRI after cardiac arrest
- The role of assessing regional areas of the brain for predicting outcome, or the use of Magnetic Resonance Spectroscopy
- Economic cost evaluation and cost-effectiveness studies on the use of CT and MRI for prognostication

Error! Reference source not found. illustrates a summary of the treatment recommendation and good practice statements.

Figure 1. Summary of treatment recommendations and good practice statement for poor outcome prediction after pediatric cardiac arrest.



Prediction of Survival With Good Neurological Outcome After Return of Circulation Following Pediatric Cardiac Arrest—Combined Prognostic SysRev (PLS 4220.05, 4220.06, 4220.07, 4220.08, SysRev 2023)

The PLS Task Force conducted a SysRev of prognostication of favorable neurologic outcome in 2023.[265] Details of this CoSTR can be found in the 2023 CoSTR summary.[124,125]

Population, Intervention, Comparator, Outcome, and Time Frame (for All Neuroprognostication)

- Population: Children (<18 years of age) who achieve a return of circulation (ROC, which includes ROSC or mechanical circulation) after resuscitation from IHCA and OHCA, from any cause
  - Studies that included newborn infants or patients in hypoxic coma from causes without a cardiac arrest (eg, respiratory arrest, toxidromes, drowning, hanging) were excluded, except when a subpopulation of cardiac arrest patients could be evaluated separately.
- Intervention: Index prognostic tests, recorded less than 12 hours, 12 to <24 hours, 24 to <48 hours, 48 to <72 hours, 72 hours to <7 days, and/or 7 to 10 days after cardiac arrest
- Comparator: There was no control group for intervention/exposure. The accuracy of the prognostic index test was assessed by comparing the predicted outcome with the final outcome, which represents the comparator.
- Outcome: Critical: prediction of survival with good neurological outcome (defined as a Pediatric Cerebral Performance Category score of 1, 2, or 3 or Vineland Adaptive Behavioral Scale-II ≥70) at the pediatric intensive care unit or hospital discharge, 1 month or later
- Time frame: January 1, 2010, to December 31, 2022

Treatment Recommendations (2023)

All evaluated tests were used in combination with other tests by clinicians in these studies. Although the predictive accuracy of tests was evaluated individually, we recommend that no single test should be used in isolation for prediction of good neurological outcome (good practice statement).

We suggest using pupillary light reflex within 12 hours after ROC for predicting good neurological outcome in children after cardiac arrest (weak recommendation, very low–certainty evidence).

We cannot make a recommendation for or against using total GCS, GCS motor score, or motor response after ROC for predicting good neurological outcome in children after cardiac arrest.

We cannot make a recommendation for or against the use of other brainstem tests after ROC for predicting good neurological outcome in children after cardiac arrest.

We suggest using a normal plasma lactate value (<2 mmol/L) up to 12 hours following ROC for predicting good neurological outcome of children after cardiac arrest (weak recommendation, very low–certainty evidence).

We cannot make a recommendation for or against using time-to-lactate-clearance within 48 hours following ROC for predicting good neurological outcome.

We suggest against using pH following ROC for predicting good neurological outcome after cardiac arrest (weak recommendation, very low–certainty evidence).

We cannot make a recommendation for or against the use of blood neuro-biomarkers (eg, S100b, NSE) after ROC for predicting good neurological outcome in children after cardiac arrest.

We suggest using EEG within 6 to 72 hours after ROC for predicting good neurological outcome in children after cardiac arrest (weak recommendation, low-certainty evidence).

We suggest using the following EEG features after ROC for predicting good neurological outcome: presence of sleep spindle and sleep II architecture at 12 to 24 hours, or continuous or normal

background EEG between 1 and 72 hours, or EEG reactivity between 6 to 24 hours (weak recommendation, very low–certainty evidence).

We suggest against using the following EEG features after ROC to predict good neurological outcome: absence of clinical or electrographic seizures; absence of status epilepticus; absence of myoclonic epilepsy; absence of burst suppression, burst attenuation, or generalized periodic epileptiform discharges; or absence of attenuated, isoelectric, or flat EEG (weak recommendation, very low–certainty evidence).

We cannot make a recommendation for or against the use of the presence or absence of N20 response SSEPs after ROC for predicting good neurological outcome.

We cannot make a recommendation for or against the use of EEG variability or EEG voltage or quantitative EEG score for predicting good neurological outcomes.

We suggest against using normal CT imaging at 24 to 48 hours from ROC for predicting good neurological outcome (weak recommendation, very low–certainty evidence).

We suggest using normal MRI between 72 hours and 2 weeks after ROC for predicting good neurological outcome (weak recommendation, low-certainty evidence).

We cannot make a recommendation for or against the use of transcranial Doppler ultrasound for predicting good neurological outcome.

Effect of Prophylactic Antiseizure Medication and/or Treatment of Seizures on Outcome of Children Following Cardiac Arrest (PLS 4210.02: SysRev 2024 CoSTR Summary)

Administration of prophylactic anti-seizure medication to prevent seizures or treatment of seizures was addressed in a SysRev in 2024, and details can be found in the 2024 CoSTR summary.[73,74]

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Adults or children in any setting (IHCA or OHCA) with ROC

- Intervention: One strategy for prophylactic anti-seizure medication OR seizure treatment
- Comparators: Another strategy or no prophylactic anti-seizure medication OR seizure treatment
- Outcomes: Critical: survival; survival with favorable neurological outcome
- Time frame: All years up to September 11, 2023

Treatment Recommendations (2024)

We suggest against the routine use of prophylactic anti-seizure medication in children post-cardiac arrest (good practice statement).

We suggest the treatment of seizures in children post-cardiac arrest (good practice statement).

Post-ROSC Oxygenation and Ventilation (PLS 4180.01 and PLS 4180.02, SysRev 2019, EvUp 2025)

Population, Intervention, Comparator, Outcome, and Time Frame

- Population: Infants and children (excluding newborn infants) who achieve ROC after out-of-hospital or in-hospital cardiac arrest
- Intervention: A ventilation and oxygenation strategy targeting a specific oxygen saturation as measured by a pulse oximeter (SpO_2), PaO_2, and/or $PaCO_2$
- Comparators: Treatment without specific targets or with an alternate target to the intervention
- Outcomes: Any clinical outcome
- Time frame: July 1, 2019, to June 20, 2024

Summary of Evidence

Our EvUp identified 4 new observational pediatric studies[304-307] on this topic. One study[306] found an association between hypoxemia and hypercapnia and the critical outcomes of favorable neurologic outcome and survival to hospital discharge, while the other studies found no overall

association. In ***1*** study[304], increased cumulative $PaCO_2$ exposure was associated with lower survival to hospital discharge among infants. An updated SysRev is warranted.

Treatment Recommendation (2020)

We suggest that rescuers measure PaO_2 after ROSC and target a value appropriate to the specific patient condition. In the absence of specific patient data, we suggest rescuers target normoxemia after ROSC (weak recommendation, very low–quality evidence).[110-112]

Given the availability of continuous pulse oximetry, targeting an oxygen saturation of 94% to 99% may be a reasonable alternative to measuring PaO_2 for titrating oxygen when feasible to achieve normoxia (based on expert opinion).[110-112]

We suggest that rescuers measure $PaCO_2$ after ROSC and target normocapnia (weak recommendation, very low–certainty evidence).[110-112]

Consider adjustments to the target $PaCO_2$ for specific patient populations where normocapnia may not be desirable (eg, chronic lung disease with chronic hypercapnia, congenital heart disease with single-ventricle physiology, increased intracranial pressure with impending herniation) (good practice statement).[110-112]

PLS Task Force PICOSTs Not Reviewed by SysRev or ScopRev (2021-2025)

A list of topics not reviewed with a SysRev of ScopRev since 2020 is provided in Table 11. In cases where an EvUp was conducted since 2020 this is indicated.

Table 11. Topics Not Reviewed With a SysRev of ScopRev Since 2020

PLS 4030.01	Adenosine use in SVT during resuscitation (EvUp 2023)
PLS 4030.04	Cardiogenic shock and inotropes
PLS 4030.08	Drugs for unstable tachycardia (SVT or wide complex)
PLS 4030.19	Prearrest care of pediatric dilated cardiomyopathy or myocarditis (EvUp 2024)
PLS 4030.31	Pre-arrest IV/IO bolus vasopressor (epinephrine)
PLS 4050.03	Pediatric METs and RRTs (EvUp 2022)
PLS 4070.01	FiO_2 titrated to oxygenation during cardiac arrest (EvUp 2023)
PLS 4070.04	Timing of intubation for IHCA
PLS 4080.02	Adhesive pads versus paddles for defibrillation
PLS 4080.06	Chest compression depth
PLS 4080.07	Chest compression only CPR versus. conventional CPR (EvUp 2022)
PLS 4080.08	CPR feedback device
PLS 4080.1	Chest compression rate
PLS 4080.11	Effect of chest compression pause duration
PLS 4080.13	Heads up CPR
PLS 4080.14	Interposed abdominal compression CPR
PLS 4080.16	One hand versus 2 hand compressions (and circumferential)
PLS 4080.2	Synced/nonsynced shock for ventricular tachycardia
PLS 4080.23	Chest compression recoil
PLS 4080.24	Chest compression-to-ventilation ratios
PLS 4080.25	Tidal volumes (chest rise)
PLS 4100.01	Family presence during resuscitation
PLS 4120.01	Ventilation rate in pediatric respiratory arrest with a perfusing rhythm present (EvUp 2024)
PLS 4150.01	Methods of calculating pediatric drug doses for cardiac arrest
PLS 4160.01	Channelopathy and consideration of etiology of arrest
PLS 4160.06	Intracardiac arrest monitoring clinical prognostic factors for cardiac arrest in infants and children
PLS 4160.12	Resuscitation of the pediatric patient with a single ventricle, post Stage I repair (EvUp 2023)
PLS 4160.13	Resuscitation of the pediatric patient with hemi-Fontan/bidirectional Glenn circulation (EvUp 2023)
PLS 4160.14	Resuscitation of the pediatric patient with single-ventricle, status-post Stage III/Fontan/total cavopulmonary connection/anastomosis (EvUp 2023)
PLS 4160.16	Point of care ultrasound for identification of reversible causes
PLS 4190.02	Post-ROSC inotrope approach
PLS 4210.01	Monitor kidney function and urine output as dialysis may be required
PLS 4210.03	Post-ROSC targeted temperature management (EvUp 2022)
PLS 4210.06	Follow-up clinics to improve survivorship
PLS 4221.01	Multimodal prognostic model for neuroprognostication

CPR indicates cardiopulmonary resuscitation; IHCA, in-hospital cardiac arrest; IO, intraosseous; IV, intravenous; MET, medical emergency team; ROSC, return of spontaneous circulation; RRT, rapid response team, and SVT, supraventricular tachycardia.

Topics retired in 2025 are listed in Table 12.

Table 12. PLS Task Force PICOSTs Retired 2025

PLS 4010.01	Atropine use for emergency intubation
PLS 4010.02	Formulas for ETT size
PLS 4020.01	Negative pressure ventilation in congenital heart disease patients
PLS 4020.02	Optimal ventilation strategy for Fontan or hemi-Fontan/bidirectional Glenn physiology in periarrest state
PLS 4020.03	Ventilation target for infants with congenital heart disease preoperatively
PLS 4030.05	Corticosteroids for septic shock
PLS 4030.06	Diagnostic tests for shock
PLS 4030.07	Distributive shock and inotropes
PLS 4030.12	Etomidate and septic shock
PLS 4030.13	Fluid resuscitation in septic shock
PLS 4030.14	Graded volume resuscitation for traumatic shock
PLS 4030.15	Timing of Intubation for shock
PLS 4030.16	Low cardiac output stage post-congenital heart disease surgery blood pressure management
PLS 4030.17	Medical treatment of excessive QP:QS circulation in neonatal congenital heart disease
PLS 4030.18	Postoperative care of child with pulmonary hypertension
PLS 4030.24	Shock vasoconstrictors
PLS 4030.26	Treatment of high-risk myocarditis patients
PLS 4030.27	Type of fluid for septic shock
PLS 4030.28	Volume of fluid for septic shock
PLS 4030.32	Cardioversion for SVT
PLS 4050.01	Cervical spine management
PLS 4080.05	Chest compression only CPR for intubated neonates outside of delivery room
PLS 4090.03	ET versus IV drugs
PLS 4110.01	Cricoid pressure for kids
PLS 4110.02	Cuffed versus uncuffed ETTs
PLS 4110.03	Verification of airway placement
PLS 4160.04	Infants and children in cardiac arrest with sepsis

ET indicates endotracheal; ETT, endotracheal tube; IV, intravenous; and SVT, supraventricular tachycardia.

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