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ILCOR SUMMARY STATEMENT

2023 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: Summary From the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces

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ABSTRACT: The International Liaison Committee on Resuscitation engages in a continuous review of new, peer-reviewed, published cardiopulmonary resuscitation and first aid science. Draft Consensus on Science With Treatment Recommendations are posted online throughout the year, and this annual summary provides more concise versions of the final Consensus on Science With Treatment Recommendations from all task forces for the year. Topics addressed by systematic reviews this year

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include resuscitation of cardiac arrest from drowning, extracorporeal cardiopulmonary resuscitation for adults and children, calcium during cardiac arrest, double sequential defibrillation, neuroprognostication after cardiac arrest for adults and children, maintaining normal temperature after preterm birth, heart rate monitoring methods for diagnostics in neonates, detection of exhaled carbon dioxide in neonates, family presence during resuscitation of adults, and a stepwise approach to resuscitation skills training. Members from 6 International Liaison Committee on Resuscitation task forces have assessed, discussed, and debated the quality of the evidence, using Grading of Recommendations Assessment, Development, and Evaluation criteria, and their statements include consensus treatment recommendations. Insights into the deliberations of the task forces are provided in the Justification and Evidence-to-Decision Framework Highlights sections. In addition, the task forces list priority knowledge gaps for further research. Additional topics are addressed with scoping reviews and evidence updates.

Key Words: AHA Scientific Statements ■ advanced life support ■ cardiac arrest ■ first aid ■ infant ■ newborn ■ pediatrics

Abbreviations and Acronyms

ACNS	American Clinical Neurophysiology Society
AED	automated external defibrillator
AHA	American Heart Association
ALS	advanced life support
aOR	adjusted odds ratio
app	application
aRR	adjusted relative risk
BIS	bispectral index
BLS	basic life support
BMV	bag-mask ventilation
COPD	chronic obstructive pulmonary disease
COSCA	core outcome set for cardiac arrest
CoSTR	International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations
CPC	Cerebral Performance Category
CPR	cardiopulmonary resuscitation
CT	computed tomography
DSED	double sequential defibrillation
ECMO	extracorporeal membrane oxygenation
ECPR	extracorporeal cardiopulmonary resuscitation
EEG	electroencephalogram
EIT	Education, Implementation, and Teams
EMS	emergency medical services
EvUp	evidence update
EXACT	Reduction of Oxygen After Cardiac Arrest Trial
FPR	false-positive rate
GCS	Glasgow Coma Scale
GRADE	Grading of Recommendations Assessment, Development, and Evaluation
GWR	gray-white matter ratio
ICU	intensive care unit
IHCA	in-hospital cardiac arrest
ILCOR	International Liaison Committee on Resuscitation
IPPV	intermittent positive-pressure ventilation
MRI	magnetic resonance imaging
mRS	modified Rankin Scale
NfL	neurofilament light
NICU	neonatal intensive care unit
NLS	neonatal life support
NSE	neuron-specific enolase
OHCA	out-of-hospital cardiac arrest
OR	odds ratio
PAD	public-access defibrillation
PICO	population, intervention, comparator, outcome
PICOST	population, intervention, comparator, outcome, study design, time frame
PICU	pediatric intensive care unit
PLS	pediatric life support
PPE	personal protective equipment
PROSPERO	Prospective Register of Systematic Reviews
RCT	randomized controlled trial
ROC	return of circulation
ROSC	return of spontaneous circulation
S100B	S100 calcium-binding protein B
ScopRev	scoping review
SD	standard defibrillation
SSEP	somatosensory evoked potential
SysRev	systematic review
THAPCA	Therapeutic Hypothermia After Pediatric Cardiac Arrest
VABS-II	Vineland Adaptive Behavior Scales Second Edition
VC	vector change
VF	ventricular fibrillation

This is the seventh in a series of annual International Liaison Committee on Resuscitation (ILCOR) International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations (CoSTR) summary publications summarizing the ILCOR task forces' analyses of published resuscitation evidence since ILCOR began the more continuous process of evidence evaluation in 2015. Including work from the 6 task forces, this year's review encompasses 90 topics reviewed in some capacity, including 25 systematic reviews (SysRevs). Although only SysRevs can generate a full CoSTR and new treatment recommendations, many other topics were evaluated with more streamlined processes.

Draft CoSTRs for all topics evaluated with SysRevs were posted on a rolling basis between April 2022 and January 2023 on the ILCOR website.[1] Each draft CoSTR includes the data reviewed and draft treatment recommendations, with public comments accepted for 2 weeks after posting. In some cases, if requested, public comment was permitted for longer. Task forces considered public feedback and provided responses. The 25 draft CoSTR statements and scoping reviews (ScopRevs) were viewed ≈20 900 times, and 76 comments were provided. All CoSTRs are now available online, adding to the existing CoSTR statements.

This summary statement contains the final wording of the treatment recommendations and good practice statements as approved by the ILCOR task forces, but it differs in several respects from the online CoSTRs: The language used to describe the evidence is not restricted to standard Grading of Recommendations Assessment, Development, and Evaluation (GRADE) terminology, making it more accessible to a wider audience; in some cases, only the high-priority outcomes are reported; the Justification and Evidence-to-Decision Framework Highlights sections are shortened in some cases but aim to provide a transparent rationale for treatment recommendations; and last, the task forces have prioritized knowledge gaps requiring future research studies. Links to the published reviews and full online CoSTRs are provided in the corresponding sections, and supporting tables and materials can be found in Appendix A.

The CoSTRs are based on analysis of the data using the GRADE approach.[2] SysRevs are conducted by expert systematic reviewers or by task force members, always with the involvement of ILCOR content experts. The GRADE approach that is part of this process rates the certainty of evidence that supports the intervention effects (predefined by the population, intervention, comparator, outcome [PICO] question) as high, moderate, low, or very low. Randomized controlled trials (RCTs) begin the analysis as high-certainty evidence, and observational studies begin the analysis as low-certainty evidence. Certainty of evidence can be downgraded for risk of bias, inconsistency, indirectness, imprecision, or publication bias; it can be upgraded for a large effect, for a dose-response effect, or if any residual confounding would be thought to decrease the detected effect.

The format for outcome data reporting varies by the data available but ideally includes both relative risk and the absolute risk difference, both with 95% CI. The absolute risk difference is the absolute difference between the risks and is calculated by subtracting the risk in the control group from the risk in the intervention group. This absolute effect enables a more clinically useful assessment of the magnitude of the effect of an intervention and enables calculation of the number needed to treat (NNT=1/RD). In cases in which the data do not allow absolute effect estimates, alternative measures of effect such as odds ratios (ORs) are reported.

Treatment recommendations are generated by the task forces after evaluating the evidence and after task force discussion. The strength of a recommendation is determined by the task force and is not necessarily tied to the certainty of evidence. Although ILCOR generally avoids providing guidance when evidence is insufficient to support a SysRev, in some cases, good practice statements have been provided for topics thought to be of particular interest to the resuscitation community. Good practice statements are not evidence-based recommendations but represent expert opinion in light of very limited data.

ILCOR's goal is to review at least 20% of all PICO questions each year so that the CoSTRs reflect current and emerging science. Acknowledging that many PICO topics will not have sufficient new evidence to warrant a SysRev, ILCOR implemented 2 additional levels of evidence review in 2020. ScopRevs are undertaken when there is a lack of clarity on the amount and type of evidence on a broader topic. Search strategies are similar in rigor to those of SysRevs, but ScopRevs do not include bias assessments or meta-analyses. The third and least rigorous form of evidence evaluation is the evidence update (EvUp), in which a minimum of a PubMed search is carried out to screen for significant new data and assess whether there has been sufficient new science to warrant a more extensive review and updated CoSTR. Both ScopRevs and EvUps can inform a decision about whether a SysRev should be undertaken but are not used to generate new or updated treatment recommendations because they do not include bias assessment, GRADE evidence evaluation, or meta-analysis. ScopRevs may be used to generate good practice statements, which represent expert opinion of the task force in light of limited evidence. In this document, ScopRevs are summarized in the relevant task force section, with references to the more complete online review. EvUps are listed at the end of each task force section in table form, with information including the prior treatment recommendation(s) related to the PICO question, how many new studies were identified, key findings, and whether an updated SysRev is recommended. Complete EvUps are provided in Appendix B.

The following topics are addressed in this CoSTR summary:

BASIC LIFE SUPPORT

- SysRevs
  - Immediate resuscitation in water or on boat in drowning
  - Automated external defibrillator (AED) use first versus cardiopulmonary resuscitation (CPR) first in drowning
  - Ventilation equipment in cardiac arrest after drowning
  - Chest compression–only CPR in drowning
  - Public-access defibrillation (PAD) programs for drowning
  - Prehospital oxygen administration in cardiac arrest after drowning
  - CPR by rescuers wearing personal protective equipment (PPE)
- ScopRevs
  - Drone delivery of AEDs
- EvUps
  - Paddle size and placement for defibrillation
  - Barrier devices
  - Chest compression rate
  - Rhythm check timing
  - Timing of CPR cycles (2 minutes versus other)
  - Public access AED programs
  - Check for circulation during basic life support (BLS)
  - Rescuer fatigue in chest compression–only CPR
  - Harm from CPR to individuals not in arrest
  - Harm to rescuers from CPR
  - Hand position during compressions
  - Dispatch-assisted compression-only versus conventional CPR
  - Emergency medical services (EMS) chest compression–only versus conventional CPR
  - Compression-ventilation ratio
  - CPR before defibrillation
  - Chest compression depth
  - Chest wall recoil
  - Foreign-body airway obstruction
  - Firm surface for CPR
  - In-hospital chest compression–only CPR versus conventional CPR
  - Analysis of rhythm during chest compressions
  - Alternative compression techniques (cough, precordial thump, fist pacing)
  - Tidal volumes and ventilation rates
  - Lay rescuer chest compression–only versus conventional CPR
  - Starting CPR (circulation-airway-breathing versus airway-circulation-breathing)
  - Dispatcher recognition of cardiac arrest
  - Resuscitation care for suspected opioid-associated emergencies
  - CPR before call for help
  - Video-based dispatch
  - Head-up CPR

ADVANCED LIFE SUPPORT

- SysRevs
  - Extracorporeal CPR (ECPR) for cardiac arrest
  - Double sequential defibrillation (DSED) for cardiac arrest with refractory shockable rhythm
  - Calcium during cardiac arrest
  - Prognostication of favorable neurological outcome
- Use of the Glasgow Coma Scale (GCS) motor score for prediction of good neurological outcome after cardiac arrest
- Imaging for prediction of good neurological outcome
- Use of brain injury biomarkers for the prediction of good outcome after cardiac arrest
- Electroencephalogram (EEG) for prediction of good neurological outcome
- Short-latency somatosensory evoked potentials (SSEPs) for prediction of good neurological outcome
- EvUps
  - Cardiac arrest in pregnancy
  - Steroids after return of spontaneous circulation (ROSC) from cardiac arrest

PEDIATRIC LIFE SUPPORT

- SysRevs
  - ECPR for cardiac arrest in pediatrics
  - Prediction of survival with good neurological outcome after return of circulation (ROC) following pediatric cardiac arrest
- Clinical examination for the prediction of survival with good neurological outcome
- Blood biomarkers for the prediction of survival with good neurological outcome
- Electrophysiology for the prediction of survival with good neurological outcome
- Brain imaging for the prediction of survival with good neurological outcome
- EvUps
  - Pulse check accuracy
  - Pad size, type, and placement for pediatric defibrillation
  - Antiarrhythmics for cardiac arrest with shockable rhythms at any time during CPR or immediately after ROSC
  - Adenosine use in supraventricular tachycardia during resuscitation
  - Energy doses for pediatric defibrillation

- Single or stacked shocks for pediatric defibrillation
- Epinephrine frequency during CPR
- Bedside ultrasound to identify perfusing rhythm
- End-tidal CO_2 monitoring during CPR
- Invasive blood pressure monitoring during CPR
- Use of near-infrared spectroscopy during cardiac arrest
- Resuscitation of the pediatric patient with a single ventricle, after stage I repair
- Resuscitation of the pediatric patient with single-ventricle, status–post–stage III/Fontan/total cavopulmonary connection/anastomosis in cardiac arrest
- Resuscitation of the pediatric patient with hemi-Fontan/bidirectional Glenn circulation in cardiac arrest
- Resuscitation of children with cardiac arrest associated with sepsis
- FIO_2 titrated to oxygenation during cardiac arrest

NEONATAL LIFE SUPPORT

- SysRevs
  - Maintaining normal temperature: preterm
  - Heart rate monitoring: diagnostic characteristics
  - Exhaled CO_2 detection to guide noninvasive ventilation
- ScopRevs
  - Heart rate to initiate chest compressions
  - Supplemental oxygen during chest compressions
  - Neonatal chest compression technique (other techniques versus 2-thumb technique)
  - Compression-to-ventilation ratio for neonatal CPR
  - Use of feedback CPR devices for neonatal cardiac arrest

EDUCATION, IMPLEMENTATION, AND TEAMS

- SysRevs
  - Family presence in adult resuscitation
  - Stepwise approach to skills training in resuscitation
- ScopRevs
  - Disparities in layperson resuscitation education
- EvUps
  - Patient outcomes from team member(s) attending a CPR course
  - Cardiac arrest centers
  - Technology to summon health care professionals
  - Futile resuscitation rules (termination of resuscitation out of hospital)
  - CPR feedback devices during training
  - CPR self-instruction versus instructor-guided training
  - In situ training

FIRST AID

- ScopRevs
  - Pulse oximetry use in the first aid setting
  - Use of supplemental oxygen in first aid
  - Recognition of anaphylaxis
  - Potential harms from bronchodilator administration

Readers are encouraged to monitor the ILCOR website[1] to provide feedback on planned SysRevs and to provide comments when additional draft CoSTRs are posted.

BASIC LIFE SUPPORT

Out-of-Hospital Cardiac Arrest After Drowning

Seven drowning questions were part of 1 large SysRev conducted by an expert review group on drowning and members of the ILCOR BLS Task Force. This SysRev was registered in International Prospective Register of Systematic Reviews (PROSPERO; CRD42021259983). A summary of the treatment recommendations for all PICO questions covered in this SysRev is given in Table 1. The same population, outcome, study design, and time frame were used for all 6 questions related to drowning.

Population, Outcome, Study Design, and Time Frame

- Population: Adults and children in cardiac arrest after drowning
- Outcomes:
  - Critical: Survival to discharge or 30 days with favorable neurological outcome and survival to discharge or 30 days
  - Important: ROSC
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Unpublished studies (eg, conference abstracts, trial protocols), manikin studies, narrative reviews, and animal studies were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract and a full-text translation was possible. The literature search was updated to April 25, 2023.

Immediate Resuscitation in Water or on Boat in Drowning (SysRev)

Rationale for Review

This topic was prioritized by the BLS Task Force after the ScopRev[3] that was completed for the 2020

Table 1. Summary of the BLS Task Force Treatment Recommendations for Drowning Resuscitation

Intervention	Lay rescuers	BLS providers with a duty to respond	EMS
On-boat resuscitation		On-boat CPR may be delivered if rescuers trained in this technique determine that it is feasible and safe to attempt resuscitation. If the rescuers feel that the application of immediate CPR is or becomes too difficult or unsafe, then the rescuers may delay resuscitation until on dry land.	
In-water resuscitation		In-water resuscitation (ventilations only) may be delivered if rescuers trained in this technique determine that it is feasible and safe with the equipment available and the distance to shore warrants its use. If the rescuers feel that the application of immediate resuscitation is too difficult or unsafe, then the rescuers may delay resuscitation until on dry land.	
AED	CPR should be started first and continued until an AED has been obtained and is ready for use. When available, an AED should be used.		
CPR	CPR starts with compressions first.*	CPR starts with ventilation first.*	
	CPR with ventilations and chest compressions Chest compression–only CPR may be considered when ventilations are not possible.		
Ventilation equipment	Mouth-to-mouth or pocket-mask ventilation	BMV can be used by rescuers who are trained in a competency-based program with regular retraining and equipment maintenance.	Follow the ALS/PLS treatment recommendations for airway management.
Oxygen		When available, use the highest possible inspired oxygen concentration.	
PAD	PAD programs should be considered in aquatic environments.		

AED indicates automated external defibrillator; ALS, advanced life support; BLS, basic life support; BMV, bag-mask ventilation; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; PAD, public-access defibrillation; and PLS, pediatric life support.

*This treatment recommendation was published in the 2022 CoSTR summary.[57,58]

CoSTR.[4,5] This SysRev was registered in PROSPERO (CRD42021259983). The full online CoSTR can be found on the ILCOR website.[6]

Intervention and Comparator

- Intervention: Immediate resuscitation in water or on boat
- Comparator: Delaying resuscitation until on land

Consensus on Science

One retrospective observational study (n=46) from coastal regions in Brazil was found that addressed in-water resuscitation,[7] and no studies were found that addressed on-boat resuscitation. In-water ventilation-only resuscitation performed by trained lifeguards compared with resuscitation delayed to land was associated with improved survival with favorable neurological outcome (52.6% versus 7.4%; relative risk, 7.1 [95% CI,1.8–28.8]) and survival to hospital discharge (52.6% versus 16.7%; relative risk, 5.7 [95% CI, 2.3–14.3]).[7]

Prior Treatment Recommendations (2005[8,9])

In-water expired-air resuscitation may be considered by trained rescuers, preferably with a flotation device, but chest compressions should not be attempted.

Individuals who are drowning should be removed from the water and resuscitated by the fastest means available.

2023 Treatment Recommendations

We suggest that in-water resuscitation (ventilations only) may be delivered if rescuers trained in this technique determine that it is feasible and safe with the equipment available and the distance to land warrants its use (weak recommendation, very low–certainty evidence).

We suggest that on-boat CPR may be delivered if rescuers trained in this technique determine that it is feasible and safe to attempt resuscitation (good practice statement).

If the rescuers feel that the application of immediate CPR is or becomes too difficult or unsafe, then the rescuers may delay resuscitation until on land (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website.[6] Key discussion points include the following:

- Hypoxemia is the leading cause of cardiac arrest in drowning.[10] Experimental and clinical data support the importance of early reversal of hypoxia as a critical intervention for improving outcomes.[7,10] The logical extension of these data is to train likely rescuers to initiate resuscitation as soon as practicable (ie, either in the water or just after removal from the water, in a boat).[3] Chest compressions are ineffective in water and should never be attempted.[11]
- In-water ventilation-only resuscitation during a rescue is feasible with proper training, sufficient rescuers, and equipment to assist with flotation.[7,12–15] Survival rates similar to those achieved by Szpilman and Soares[7] were reported in a case series from Australia in trained lifeguards performing in-water resuscitation in deep water.[15] As identified in the ILCOR ScopRev on drowning,[3] to avoid risks to the patient and themselves, rescuers

need to consider their own safety, including the weather and water conditions, distance to land, and the availability of supportive and floating equipment and additional rescuers. Training should also include important learnings from manikin studies such as avoiding the unintentional submersion of the patient[12,13,16] and the potential for fatigue and failed rescue.[12,16]

- The good practice statement on resuscitation in boats was informed by observational and simulation studies showing that it is feasible for rescuers trained in this technique to initiate resuscitation on moving boats.[17–22] This recommendation applies to rescue boats and is not meant for the lay public.
- Organizations developing guidelines from these recommendations should consider local conditions, including the type and size of the rescue vessel, the number of available rescuers, the availability of equipment and training, and the characteristics of the water and land.
- For both in-water and in-boat resuscitation, the drowning expert group and the BLS Task Force emphasize the importance of continuous assessment of the safety and efficacy while performing these interventions. If either or both are compromised, rescuers should prioritize rescue and delay resuscitation until on land.

Task Force Knowledge Gaps

- High-quality evidence evaluating the impact of immediate (in-water ventilation and on-boat) compared with delayed resuscitation on patient outcomes, CPR quality, and rescuer safety is required.
- To enable future reviews and meta-analysis, data collection should be standardized and guided by the Utstein Drowning Statement,[23,24] CPR metrics recommended by the American Heart Association (AHA),[25] and core outcome set for cardiac arrest (COSCA) outcomes.[26,27]

AED Use First Versus CPR First in Cardiac Arrest in Drowning (SysRev)

Rationale for Review

AED use in drowning was covered in the ILCOR ScopRev.[3] The BLS Task Force prioritized 2 questions relating to AED use. This first question explored whether CPR or AED use should be prioritized in cardiac arrest after drowning. This SysRev was registered in PROSPERO (CRD42021259983). The full text of this CoSTR can be found on the ILCOR website.[28]

Intervention and Comparator

- Intervention: AED administered before CPR
- Comparator: CPR administered before AED

Consensus on Science

No studies were identified that addressed the population, intervention, comparator, outcome, study design, and time frame (PICOST) question.

Prior Treatment Recommendations

None specific to drowning

2023 Treatment Recommendations

We recommend that CPR should be started first and continued until an AED has been obtained and is ready for use for adults and children in cardiac arrest caused by drowning (good practice statement).

When available, we recommend an AED be used in cardiac arrest caused by drowning in adults and children (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website.[28] Key discussion points include the following:

- In 2020, the ILCOR SysRev (for cardiac arrest of all causes) found low-certainty evidence with no clear benefit for CPR before defibrillation in a meta-analysis.[4,5] The 2020 recommendation of beginning with CPR first during unmonitored cardiac arrests while the defibrillator is prepared was based on a lack of new evidence since the 2015 review and the value of remaining consistent with the previous treatment recommendation.[4,5]
- We found no evidence that directly examined this question in the specific context of drowning. The rationale for CPR first is based on the hypoxic mechanism of cardiac arrest in drowning[29] and the low incidence of shockable rhythm in drowned out-of-hospital cardiac arrests (OHCAs) found in our prior ScopRev.[3] Nevertheless, cardiac arrest after drowning may be a primary cardiac event in some adults and children.[30]
- For these reasons and because the 2021 ILCOR ScopRev on drowning did not find evidence of harm[3] and AEDs are associated with improved outcomes generally,[31] we recommend that an AED should be used in cardiac arrests after drowning once CPR has started. Training and guidelines should highlight the importance of drying the chest and ensuring that the patient is not in water during attempted defibrillation.

Task Force Knowledge Gaps

- High-quality evidence of the effectiveness of AED use on outcomes, CPR quality, and safety in drowned patients is required.
- To enable future reviews and meta-analysis, data collection should be standardized and guided by the Utstein Drowning Statement,[23,24] AHA-recommended CPR metrics,[25] and COSCA outcomes.[26,27]

Ventilation Equipment in Cardiac Arrest After Drowning (SysRev)

Rationale for Review

This topic was prioritized by the BLS Task Force after the ScopRev[3] that was completed for the 2020 CoSTR.[4,5] This SysRev was registered in PROSPERO (CRD42021259983). The full text of this CoSTR can be found on the ILCOR website.[32]

Intervention and Comparator

- Intervention: Ventilation with equipment before hospital arrival
- Comparator: Ventilation without equipment before hospital arrival

Consensus on Science

No studies were identified that addressed the PICOST question.

Prior Treatment Recommendations

None specific to drowning

2023 Treatment Recommendations

We recommend using mouth-to-mouth, mouth-to-nose, or pocket-mask ventilation by BLS providers and laypeople for adults and children in cardiac arrest caused by drowning (good practice statement).

We suggest that bag-mask ventilation (BMV) can be used by lifeguards or other BLS providers with a duty to respond, on the condition that it is part of a competency-based training program with regular retraining and maintenance of equipment (good practice statement).

We recommend that health care professionals follow the advanced life support (ALS) treatment recommendations for airway management for adults and children in cardiac arrest caused by drowning.[33,34]

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website.[32] Key discussion points include the following:

- In making these treatment recommendations, we considered the following indirect evidence from retrospective studies comparing airway and ventilation equipment in drowning. One study reported that the use of a supraglottic airway was associated with lower odds of survival to hospital admission compared with tracheal intubation (adjusted OR [aOR], 0.56 [95% CI, 0.42–0.76]) and lower odds of survival to discharge (aOR, 0.40 [95% CI, 0.19–0.86]) compared with BMV.[35] A case study argued that an supraglottic airway might be unsuitable for drowned patients because of low lung compliance and high airway resistance.[36] Two studies in children showed worse outcomes with EMS tracheal intubation of children compared with BMV (OR, 0.04 [95% CI, 0.01–0.20][37]; OR, 0.25 [95% CI, 0.08–0.83][38]); however, tracheal intubation is also an indicator of severity of injury in drowned OHCAs.[3]
- We found no evidence to suggest a change from current BLS, ALS, and pediatric life support (PLS) treatment recommendations for BLS providers, laypeople, and health care professionals.[33,34,39–42] In making the conditional treatment recommendation for the use of BMV by non–health care professionals with a duty to respond such as lifeguards, the review group and BLS Task Force considered the following: that drowning resuscitation is likely to be initially performed by these groups; that there is widespread use of BMV by lifeguards in some regions, as well as a need for a BMV treatment recommendation to ensure safe practice in the use of this equipment; that work conditions (professional/volunteer), availability of equipment, and training widely vary both between and within countries; that BMV can be difficult to perform[43] and requires competency-based training, retraining, and monitoring; and that BMV equipment needs to be regularly checked and maintained.

Task Force Knowledge Gaps

- High-quality evidence evaluating airway and ventilation strategies on patient outcomes and CPR quality is needed.
- To enable future reviews and meta-analysis, data collection should be standardized and guided by the Utstein Drowning Statement,[23,24] AHA-recommended CPR metrics,[25] and COSCA outcomes.[26,27]

Chest Compression–Only CPR in Cardiac Arrest in Drowning (SysRev)

Rationale for Review

This topic was prioritized by the BLS Task Force after the review of CPR in drowning in the ScopRev[3] that was completed for the 2020 CoSTR.[4,5] This SysRev was registered in PROSPERO (CRD42021259983). The full text of this CoSTR can be found on the ILCOR website.[44]

Intervention and Comparator

- Intervention: Chest compression–only CPR
- Comparator: Conventional CPR (compressions and ventilations)

Consensus on Science

Two retrospective observational studies were identified that addressed the PICOST question in bystander CPR and provided very low–certainty evidence for all outcomes.[45,46] There was no difference between groups in either study for survival with favorable neurological outcome or ROSC.[45,46] One study[45] found no difference in 30-day survival, whereas the other[46] found that

conventional CPR was associated with increased survival to discharge overall (aOR, 1.54 [95% CI, 1.01–2.36]; *P*=0.046) and, in a post hoc subgroup analysis, documented increased odds of favorable neurological outcome in children 5 to 15 years of age (aOR, 2.68 [95% CI, 1.10–6.77]; *P*=0.03).

Prior Treatment Recommendations

None specific to drowning

2023 Treatment Recommendations

For lay responders, the treatment recommendations for CPR in drowned patients with OHCA who have been removed from the water remain consistent with CPR for all patients in cardiac arrest (good practice statement).

For adults, we recommend that bystanders perform chest compressions for all patients in cardiac arrest.[4,5] We suggest that bystanders who are trained, able, and willing to give rescue breaths and chest compressions do so for adults in cardiac arrest.[4,5]

We suggest that bystanders provide CPR with ventilation for infants and children <18 years of age with OHCA.[39,40] We recommend that if bystanders cannot provide rescue breaths as part of CPR for infants and children <18 years with OHCA, they should at least provide chest compressions.[39,40]

For health care professionals and those with a duty to respond to drowning (eg, lifeguards), we recommend providing ventilation in addition to chest compressions if they have been trained and are able and willing to do so (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website and the evidence-to-decision table can be found in Appendix A.[44] Key discussion points include the following:

- Cardiac arrest in drowning is primarily the result of a lack of oxygen in the blood.[29] Therefore, providing ventilation in CPR in drowning is important.
- The existing evidence, from 2 registry studies comparing conventional CPR with compression-only CPR,[45,46] is at high risk of bias and is considered very low–certainty evidence. Although we acknowledge that bystanders are more willing to perform compression-only CPR, particularly on strangers,[47] and compression-only CPR is well known in some regions,[48] CPR with ventilations and compression in drowning is the preferred method of CPR when bystanders are capable and trained. Compression-only CPR should be considered only if ventilations are not possible.

Task Force Knowledge Gaps

- High-quality evidence evaluating the effect of different CPR strategies on patient outcomes is needed. Such studies should stratify by the patient's age (adults and children) and adjust for important confounders.[23,24]
- To enable future reviews and meta-analysis, data collection should be standardized and guided by the Utstein Drowning Statement,[23,24] AHA-recommended CPR metrics,[25] and COSCA outcomes.[26,27]

PAD Programs for Drowning (SysRev)

Rationale for Review

AED use in drowning was covered in the ILCOR ScopRev.[3] The BLS Task Force prioritized 2 questions relating to AED use. This second question explored PAD programs for drowning. This SysRev was registered in PROSPERO (CRD42021259983). The full text of this CoSTR can be found on the ILCOR website.[49]

Intervention and Comparator

- Intervention: PAD program
- Comparator: Absence of PAD program

Consensus on Science

No studies were identified that addressed the PICOST question.

Prior Treatment Recommendations

None specific to drowning

2023 Treatment Recommendations

This treatment recommendation is unchanged from the standing recommendation for all OHCAs.

We recommend implementing PAD programs for all patients with OHCA (strong recommendation, low-certainty evidence).[4,5]

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website.[49] Key discussion points include the following:

- The BLS Task Force and review group considered that drowning often occurs in high-use public spaces where AED placement may benefit both drowning and nondrowning OHCAs. No adverse events were noted related to AED use in drowning in the ILCOR ScopRev.[3] AEDs should be properly signposted—and ideally registered with EMS or in AED registries—and available and accessible for use in nearby OHCAs.[50,51] We recognize that PAD programs may not be feasible to implement in low-resource settings due to associated costs for equipment, training, and maintenance.

Task Force Knowledge Gaps

- High-quality evidence evaluating the effectiveness of AED programs in aquatic environments on patient outcomes, CPR metrics, and safety, including their cost effectiveness, is needed.
- It is unclear to what extent traditional PAD program coverage includes aquatic settings and the cost-benefit ratio in these settings.

- To enable future reviews and meta-analysis, data collection should be standardized and guided by the Utstein Drowning Statement,[23,24] AHA-recommended CPR metrics,[25] and COSCA outcomes.[26,27]

Prehospital Oxygen Administration in Cardiac Arrest After Drowning (SysRev)

Rationale for Review

This topic was prioritized by the BLS Task Force after the ScopRev[3] that was completed for the 2020 CoSTR.[4,5] This SysRev was registered in PROSPERO (CRD42021259983). The full text of this CoSTR can be found on the ILCOR website.[52]

Intervention and Comparator

- Intervention: Oxygen administration before hospital arrival
- Comparator: No oxygen administration before hospital arrival

Consensus on Science

No studies were identified that addressed the PICOST question.

Prior Treatment Recommendations

None specific to drowning

2023 Treatment Recommendation

When available, we recommend that trained providers use the highest possible inspired oxygen concentration during resuscitation for adults and children in cardiac arrest after drowning (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website.[52] Key discussion points include the following:

- This treatment recommendation is based on the understanding that most cardiac arrests in drowning are caused by low oxygen in the blood (ie, hypoxemia)[29] and supplemental oxygen administered by trained providers is likely to be beneficial. We also note that indirect observational research found in the ILCOR ScopRev on drowning suggests that hypoxemia in submerged patients is associated with worse patient outcomes.[3]
- This good practice statement focuses on oxygen during resuscitation from drowning. The results of the recent EXACT RCT (Reduction of Oxygen After Cardiac Arrest Trial) do not support the prehospital titration of oxygen in successfully resuscitated adults with presumed OHCA.[53] We recommend following ILCOR's ALS and PLS treatment recommendations for oxygen titration after ROSC. However, we also recognize that peripheral vasoconstriction may make pulse oximetry unreliable after drowning. Although 2 simulation studies in healthy subjects suggest that pulse oximetry is feasible and reliable after immersion for up to 30 minutes,[54,55] we found no data on the reliability of pulse oximetry in drowned patients. Furthermore, a recent meta-analysis reports that pulse oximetry may overestimate oxygen saturation in people with dark skin pigmentation.[56]
- Oxygen therapy is expensive in terms of the equipment, maintenance, and training required for effective delivery. Oxygen is already available in some aquatic settings such as pools and beaches staffed by lifeguards for use in drowning resuscitations. The use of supplemental oxygen has regulatory restrictions in some countries, and access to it may be limited in low- and middle-income countries. Those responsible for deciding whether to make oxygen therapy available will need to weigh the costs, regulatory requirements, setting, skills and training needs of those with a duty to respond, and time taken for an ALS health care professional to arrive with oxygen against the potential but uncertain benefits. Safe storage of oxygen should be regulated and should be part of the training.

Task Force Knowledge Gaps

- High-certainty evidence evaluating the effect of early oxygen therapy on patient outcomes, safety, and cost benefit is needed.
- To enable future reviews and meta-analysis, data collection should be standardized and guided by the Utstein Drowning Statement,[23,24] AHA-recommended CPR metrics,[25] and COSCA outcomes.[26,27]

CPR by Rescuers Wearing PPE (SysRev)

Rationale for Review

This topic was prioritized by the BLS Task Force because the coronavirus disease 2019 (COVID-19) pandemic has resulted in increased use of PPE, which may increase fatigue and affect CPR quality and patient outcomes. (The risk of illness transmission was not included as an outcome in this review because it was covered by a separate ILCOR SysRev.[59]) This SysRev was registered in PROSPERO (CRD42022347746).[60] The full text of this CoSTR can be found on the ILCOR website.[61]

PICOST

- Population: Adults and children in any setting (in hospital or out of hospital) with cardiac arrest (including simulated cardiac arrest)
- Intervention: CPR by rescuers wearing PPE
- Comparators: CPR by rescuers not wearing PPE
- Outcomes:
  - Critical: Survival to discharge and ROSC

- Important: CPR quality, time to the procedure of interest, and rescuer's fatigue and neuropsychiatric performance such as concentration and dexterity
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Unpublished studies (eg, conference abstracts, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to May 23, 2022.

Consensus on Science

The search strategy found 1 clinical study[62] and 10 simulation studies (6 RCTs[63–68] and 4 non-RCTs[69–72]) comparing PPE with no PPE. In studies included in the meta-analyses, the types of PPE examined varied, but the minimum was level C (gloves, chemical-resistant clothing, and a respirator mask with filter). In studies comparing different types of PPE, there was too much variation in the type of PPE worn, and these studies were not analyzed.

A before-and-after observational study comparing conventional PPE (surgical mask, gloves, and gown) with enhanced PPE (complete bodysuit, boots, N95 respirator, and powered air-purifying respirator) in an emergency department setting reported no difference in 30-day survival (aOR, 0.38 [95% CI, 0.07–2.10]; *P*=0.27) or ROSC (aOR, 0.79 [95% CI, 0.38–1.67]; *P*=0.54) in the enhanced PPE period.[62]

A meta-analysis of simulation RCTs and observational studies showed no difference for key measures of CPR quality in rescuers wearing PPE compared with no PPE (Table 2). Two observational studies reported increased self-reported fatigue in the group wearing PPE (absolute risk reduction, visual analog scale score 2.7 of 10 [95% CI, 1.4–4.0]).[69,70] Of the 3 simulation studies that examined time to CPR, 1 neonatal study reported slightly longer time to the start of ventilation with full PPE[73] compared with no PPE, and 2 adult studies reported longer time to compressions with increasing levels of PPE.[22,74]

Prior Treatment Recommendations

None

2023 Treatment Recommendations

We recommend monitoring for fatigue in all rescuers performing CPR (good practice statement).

We suggest increased vigilance for fatigue in rescuers wearing PPE (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[61] Key discussion points include the following:

- In making this treatment recommendation, we put a high value on protecting health care professionals from potential infection transmission and on consistency with current recommendations on using PPE during resuscitation.
- The delivery of chest compressions is physically tiring. In the 2 studies reporting greater fatigue in the groups wearing PPE, CPR was performed in pairs, and the person performing chest compressions was changed every 2 minutes.[69,70] Although both studies reported worse CPR quality with PPE, the overall results of our meta-analysis show no effect on CPR quality. The studies included in this review were predominantly simulation, manikin-based studies and varied significantly in the procedures used, including the type of PPE, the design of simulated scenarios, the duration of CPR performed, and the measures of CPR quality used. Therefore, results should be interpreted carefully and may not be generalizable to the clinical setting.
- There was a lack of clinical studies examining the impact of PPE on patient outcomes. The BLS Task Force considered a treatment recommendation that included an option to shorten CPR cycles when PPE is worn; however, we decided against

Table 2. CPR Quality Outcomes for Randomized and Observational Simulation Studies Comparing PPE With No PPE

Outcome	Studies	Certainty of evidence	Mean difference (95% CI)
Compression depth	5 RCTs[63–67]	Very low	1.8 mm (−4.3 to 0.8)
	4 observational[69–72]	Very low	4.4 mm (−8.9 to 0.1)
Compression rate	5 RCTs[63–67]	Very low	1.0 per minute (−5.8 to 3.7)
	4 observational[69–72]	Very low	2.4 per minute (−5.9 to 1.2)
Appropriate compression depth	4 RCTs[65–68]	Very low	6.5% (−25.3 to 12.2)
Appropriate compression rate	3 RCTs[66–68]	Very low	3.7% (−18.3 to 10.9)
Hands-off time	2 RCTs[67,68]	Very low	5.1 s (−1.7 to 11.8)
Appropriate chest recoil	2 RCTs[64,68]	Very low	4.3% (0.8 to 7.8)
Rescuer fatigue	2 observational[69,70]	Very low	VAS score 2.7 of 10 (1.4 to 4.0)

RCT indicates randomized controlled trial; and VAS, visual analog scale.

this because there was no overall evidence that PPE influenced CPR quality, and a shorter CPR cycle may also increase hands-off-chest time.[76] An ILCOR SysRev in 2019 in adults and children also suggested against pausing chest compressions at intervals other than every 2 minutes to assess the cardiac rhythm.[41]

Task Force Knowledge Gaps

Current knowledge gaps include the following:

- The effect of PPE on time to CPR start, CPR quality, and patient outcomes in actual resuscitation
- The relationship among PPE use, CPR duration, and rescuer fatigue
- The best type of PPE or appropriate modification strategies to mitigate rescuer fatigue

Drone Delivery of AEDs (ScopRev)

Rationale for Review

This topic was chosen for ScopRev by the BLS Task Force because of increasing worldwide interest in drone-delivered AEDs for OHCA. No previous ILCOR review or ScopRev existed to give an overview and status of this emerging field. The full text of this CoSTR can be found on the ILCOR website.[77]

PICOST

- Population: Adults and children with OHCA
- Intervention: Drone-delivered AEDs
- Comparator: Standard EMS response times (or time for EMS-delivered AED) and AEDs delivered by bystanders (or activated volunteer responders)
- Outcome: Real-world/estimated feasibility, time gain of drone-delivered AEDs (compared with standard EMS delivery), predicted survival, predicted quality-adjusted life-years gained, cost-effectiveness, and calculated proportion of defibrillation and survival compared with cases in which AEDs are brought to the OHCA scene by standard means.
- Study design: Theoretical feasibility studies, prediction models (eg, spatial analysis, geographic information system models), observational studies, simulation studies, qualitative studies of human-drone interaction, and real-world feasibility studies. Unpublished studies (eg, conference abstracts, trial protocols) were excluded.
- Time frame: English languages studies published to December 1, 2022.

Summary of Evidence

The evidence was divided into the following 3 categories:

- Computer/prediction models: 17 studies used different strategies to localize optimal sites for placement of AED-drone bases and to estimate time gain compared with EMS response time.[35,78–93] The data used varied according to geographic areas, quality and accessibility of historical OHCA data, drone type and input of diverse drone-flight details, existing EMS system, and volunteer responder programs.
- Test flights/simulation studies and qualitative analysis: 9 studies of various aims, geography, and testing areas.[94–102]
- Real-life drone AED delivery for OHCA: One feasibility study examined 14 suspected OHCAs eligible for drone takeoff in which 12 drone flights were performed and successful AED delivery was achieved in 11 of 12 suspected OHCA incidents (92%).[103] A drone AED arrived before the ambulance in 64% of cases. The success rate of AED delivery was 90% among 61 additional beyond-visual-line-of-sight test flights. The other study was a case report with the first-ever person reported to survive after OHCA and defibrillation with a drone-delivered AED.[104]

All included studies (from all 3 categories) found drone delivery of AEDs to be feasible. One qualitative study highlights the importance of assessing the community's cardiac arrest literacy levels, information needs, and readiness for innovation to ensure successful uptake in smaller communities.[101] Five cost-effectiveness studies predicted the cost-effectiveness of a drone AED system to supplement existing systems to secure early defibrillation.[78,79,86,89,91]

Task Force Insights

A limited evidence base was identified, with most studies focused on theoretical drone base placement and estimated AED drone delivery times compared with standard EMS times. In contrast, only 1 pilot study and 1 case study reported the drone delivery of AEDs to real-world OHCAs. Air Traffic Control and regulatory aspects concerning Specific Operations Risk Assessment are the major obstacles in the widespread use of AED-delivering drones beyond line of sight.

Future studies should examine the delivery of AEDs to real-world patients with OHCA and document the impact on patient outcomes. No RCTs were identified concerning AED delivery by drones.

Treatment Recommendations

The heterogeneity of the studies and the lack of data on patient outcomes do not currently support the need for a specific SysRev or a meta-analysis.

BLS Topics Reviewed by EvUps

Topics reviewed by EvUps are summarized in Table 3, with the PICO, existing treatment recommendation, number of studies identified, key findings, and whether a SysRev was deemed worthwhile provided. Complete EvUps can be found in Appendix B.

Table 3. BLS Topics Reviewed by EvUps

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
ALS-E-030A, paddle size and placement for defibrillation	2010 (ScopRev 2020)	It is reasonable to place pads on the exposed chest in an anterior-lateral position. An acceptable alternative position is anterior posterior. In large-breasted individuals, it is reasonable to place the left electrode pad lateral to or underneath the left breast, avoiding breast tissue. Consideration should be given to the rapid removal of excessive chest hair before the application of pads, but emphasis must be on minimizing delay in shock delivery. There is insufficient evidence to recommend a specific electrode size for optimal external defibrillation in adults. However, it is reasonable to use a pad size >8 cm.	1	1	RCT in refractory VF (anterior-posterior position vs sternal-apical+DSED): survival to hospital discharge (RR, 1.71 [95% CI, 1.01–2.88]) Retrospective observational study (n=484): No difference was observed in defibrillation efficacy between anterior-posterior and sternal-apical pad placement.	No (refractory VF; see ALS CoSTR DSED)
BLS 342, barrier devices	2005	Providers should take appropriate safety precautions when feasible and when resources are available to do so, especially if the individual is known to have a serious infection (eg, HIV, tuberculosis, HBV, or SARS).	0	0	No new studies identified	No
BLS 343, chest compression rate	2015 (ScopRev 2020)	We recommend a manual chest compression rate of 100–120/min (strong recommendation, very low–certainty evidence).	0	6	Six new observational studies on rate and depth, but not recoil, since last ScopRev. Findings are consistent with current guidelines	No
BLS 345, rhythm check timing	2020	We suggest immediate resumption of chest compressions after shock delivery for adults in cardiac arrest in any setting (weak recommendation, very low–certainty evidence).	0	0	No new studies identified	No
BLS 346, timing of CPR cycles (2 min vs other)	2020	We suggest pausing chest compressions every 2 min to assess the cardiac rhythm (weak recommendation, low-certainty evidence).	0	0	No new studies identified	No
BLS 347, public-access AED programs	2020	We recommend the implementation of PAD programs for patients with OHCAs (strong recommendation, low-certainty evidence).	0	3	Introduction of a PAD program at Tokyo railroad stations presented significant benefits and cost-effectiveness in line with previous recommendations. The annual rate of SCDs in Japanese individuals 5–64 y of age decreased after implementation of a national PAD program. A Canadian study reported that longer time to AED access was associated with lower survival to discharge.	No
BLS 348, check for circulation during BLS	2015	Outside of the ALS environment, where invasive monitoring is available, there are insufficient data on the value of a pulse check while performing CPR. We therefore do not make a treatment recommendation for the value of a pulse check.	0	0	No new studies. Some relevant articles showing the effectiveness of ultrasound to check for circulation were identified.	No
BLS 349, rescuer fatigue in CCO-CPR	2015	We recommend no modification to current CCO-CPR guidelines for cardiac arrest to mitigate rescuer fatigue (strong recommendation, very low–certainty evidence).	0	0	No new studies	No

(*Continued*)

Table 3. Continued

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
BLS 353, harm from CPR to individuals not in arrest	2020	We recommend that laypeople initiate CPR for presumed cardiac arrest without concerns of harm to patients not in cardiac arrest (strong recommendation, very low–certainty evidence).	0	0	No new studies identified	No
BLS 354, harm to rescuers from CPR	2015 (ScopRev 2020)	Evidence supporting rescuer safety during CPR is limited. The few isolated reports of adverse effects resulting from the widespread and frequent use of CPR suggest that performing CPR is relatively safe. Delivery of a defibrillator shock with an AED during BLS is also safe. The incidence and morbidity of defibrillator-related injuries in the rescuers are low.	0	3	One study found low risk of physical injury in citizen responders dispatched to OHCA. One study reported slightly greater pain with 2-handed (vs 1-handed) CPR in children. One study found low risk of harm from defibrillation in rescuers wearing polyethylene gloves.	No
BLS 357, hand position during compressions	2020	We suggest performing chest compressions on the lower half of the sternum on adults in cardiac arrest (weak recommendation, very low–certainty evidence).	0	0	No new studies addressed this question, but 2 simulation/training studies highlighted difficulties for lay rescuers in identifying correct hand position. No new studies in 2022	No
BLS 360, EMS CCO-CPR vs conventional CPR	2020	We recommend that EMS providers perform CPR with 30 compressions to 2 breaths (30:2 ratio) or continuous chest compressions with positive pressure ventilation delivered without pausing chest compressions until a tracheal tube or supraglottic device has been placed (strong recommendation, high-certainty evidence). We suggest that, when EMS systems have adopted minimally interrupted cardiac resuscitation, this strategy is a reasonable alternative to conventional CPR for witnessed shockable OHCA (weak recommendation, very low–certainty evidence).	0	1	One new study in 2021. Median inspiratory tidal volume generated by manual chest compressions without ventilation was 20 mL (IQR 13–28 mL), which was judged as inadequate to provide adequate alveolar ventilation.	No
BLS 362, CV ratio	2017	We suggest a CV ratio of 30:2 compared with any other CV ratio in patients with cardiac arrest (weak recommendation, very low–quality evidence).	0	0	No new studies identified	No
BLS 363, CPR before defibrillation	2020	We suggest a short period of CPR until the defibrillator is ready for analysis and/or defibrillation in unmonitored cardiac arrest (weak recommendation, low-certainty evidence).	0	0	No new studies identified	No
BLS 366, chest compression depth	2015 (ScopRev 2020)	We recommend a chest compression depth of ≈5 cm (2 in; strong recommendation, low-certainty evidence) while avoiding excessive chest compression depths (>6 cm [>2.4 in] in an average adult) during manual CPR (weak recommendation, low-certainty evidence).	0	6	Six new observational studies since last ScopRev Findings consistent with current guidelines	No
BLS 367, chest wall recoil	2015 (ScopRev 2020)	We suggest that rescuers performing manual CPR avoid leaning on the chest between compressions to allow full chest wall recoil (weak recommendation, very low–quality evidence).	0	4	Four new observational studies on chest wall recoil since last ScopRev Findings consistent with current guidelines	No

(*Continued*)

Table 3. Continued

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
BLS 368, foreign-body airway obstruction	2020	We suggest that backslaps are used initially in adults and children with a foreign-body airway obstruction and an ineffective cough (weak recommendation, very low–certainty evidence). We suggest that abdominal thrusts are used in adults and children (>1 y of age) with a foreign-body airway obstruction and an ineffective cough when backslaps are ineffective (weak recommendation, very low–certainty evidence). We suggest that rescuers consider the manual extraction of visible items in the mouth (weak recommendation, very low–certainty evidence). We suggest against the use of blind finger sweeps in patients with a foreign-body airway obstruction (weak recommendation, very low–certainty evidence). We suggest that appropriately skilled health care providers use Magill forceps to remove a foreign-body airway obstruction in patients with OHCA from foreign-body airway obstruction (weak recommendation, very low–certainty evidence). We suggest that chest thrusts be used in unconscious adults and children with a foreign-body airway obstruction (weak recommendation, very low–certainty evidence). We suggest that bystanders undertake interventions to support foreign-body airway obstruction removal as soon as possible after recognition (weak recommendation, very low–certainty evidence). We suggest against the routine use of suction-based airway clearance devices (weak recommendation, very low–certainty evidence).	0	1	A single new case series described 8 cases of the use of a vacuum cleaner to clear foreign-body airway obstruction. No new studies in 2022	No
BLS 370, firm surface for CPR	2020	We suggest performing chest compressions on a firm surface when possible (weak recommendation, very low–certainty evidence). During in-hospital cardiac arrest, we suggest that, when a bed has a CPR mode that increases mattress stiffness, it should be activated (weak recommendation, very low–certainty evidence). During in-hospital cardiac arrest, we suggest against moving a patient from a bed to floor to improve chest compression depth (weak recommendation, very low–certainty evidence). During in-hospital cardiac arrest, we suggest in favor of either a backboard or no-backboard strategy to improve chest compression depth (conditional recommendation, very low–certainty evidence).	3	0	Three manikin RCTs identified in 2021 No new studies in 2022	No
BLS 372, in-hospital CCO-CPR vs conventional CPR	2017	Whenever tracheal intubation or a supraglottic airway is achieved during in-hospital CPR, we suggest that providers perform continuous compressions with positive-pressure ventilation delivered without pausing chest compressions (weak recommendation, very low–certainty evidence).	0	0	No new studies identified	No

(*Continued*)

Table 3. Continued

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
BLS 373, analysis of rhythm during chest compression	2020	We suggest against the routine use of artifact-filtering algorithms for analysis of electrocardiographic rhythm during CPR (weak recommendation, very low–certainty evidence). We suggest that the usefulness of artifact-filtering algorithms for analysis of electrocardiographic rhythm during CPR be assessed in clinical trials or research initiatives (weak recommendation, very low–certainty evidence).	0	3	Three new observational studies since last SysRev Analysis during CPR leads to fewer pauses in chest compressions. High proportion of rhythms were unable to be assessed by algorithm (43%). No studies reported patient outcomes.	No
BLS 374, alternative compression techniques (cough, precordial thump, fist pacing)	2020	We recommend against the routine use of cough CPR for cardiac arrest (strong recommendation, very low–certainty evidence). We suggest that cough CPR may be considered only as a temporizing measure in exceptional circumstance of a witnessed, monitored IHCA (eg, in a cardiac catheterization laboratory) if a nonperfusing rhythm is recognized promptly before loss of consciousness (weak recommendation, very low–certainty evidence). We recommend against fist pacing for cardiac arrest (strong recommendation, very low–certainty evidence). We suggest that fist pacing may be considered only as a temporizing measure in the exceptional circumstance of a witnessed, monitored IHCA (eg, in a cardiac catheterization laboratory) due to bradyasystole if such a nonperfusing rhythm is recognized promptly before loss of consciousness (weak recommendation, very low–certainty evidence). We recommend against the use of a precordial thump for cardiac arrest (strong recommendation, very low–certainty evidence).	0	0	No new studies identified	No
BLS 546, tidal volumes and ventilation rates	2010	For mouth-to-mouth ventilation for adults using exhaled air or BMV with room air or oxygen, it is reasonable to give each breath within a 1-s inspiratory time and with an approximate volume of 600 mL to achieve chest rise. It is reasonable to use the same initial tidal volume and rate in patients regardless of the cause of the cardiac arrest.	0	0	No new studies identified	No
BLS 547, lay rescuer CCO-CPR vs standard CPR	2020	We continue to recommend that bystanders perform chest compressions for all patients in cardiac arrest (good practice statement). We suggest that bystanders who are trained, able, and willing to give rescue breaths and chest compressions do so for all adult patients in cardiac arrest (weak recommendation, very low–certainty evidence).	0	0	Only manikin/training studies since 2020 No new studies in 2022	No
BLS 661, starting CPR (CAB vs ABC)	2020 CoSTR	We suggest starting CPR with compressions rather than ventilation in adults with cardiac arrest (weak recommendation, very low–certainty evidence).	0	0	No new studies identified in 2021 or 2022 in adults	No

(*Continued*)

Table 3. Continued

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
BLS 811, resuscitation care for suspected opioid-associated emergencies	2020	We suggest that CPR be started without delay in any unconscious person not breathing normally and that naloxone be used by lay rescuers in suspected opioid-related respiratory or circulatory arrest (weak recommendation based on expert consensus).	0	0	No new studies identified	No
BLS 1527, CPR before call for help	2020	We recommend that a lone bystander with a mobile phone should dial EMS, activate the speaker or other hands-free option on the mobile phone, and immediately begin CPR with dispatcher assistance, if required (strong recommendation, very low–certainty evidence).	0	0	No new studies identified	No
BLS video-based dispatch	2021	We suggest that the usefulness of video-based dispatch systems be assessed in clinical trials or research initiatives (weak recommendation, very low–certainty evidence).	2: manikin (pediatric and infant)	2	Two observational studies were identified in 2021. Of 2 new manikin RCTs in 2022, 1 reported better CPR quality with video compared with T-CPR in untrained participants but also longer times (eg, to recognition, first compression). The other reported no difference in the evaluation for foreign-body airway obstruction.	No
BLS head-up CPR	2021	We suggest against the routine use of head-up CPR during CPR (weak recommendation, very low–certainty evidence). We suggest that the usefulness of head-up CPR during CPR be assessed in clinical trials or research initiatives (weak recommendation, very low–certainty evidence).	0	2	Two new studies were identified in 2022. One observational study found no difference in survival outcomes overall and suggested improved outcomes with rapid initiation. One pilot observational study reported increased cerebral blood flow with head-up positioning during CPR.	No

ABC indicates airway-breathing-circulation; AED, automated external defibrillator; ALS, advanced life support; BLS, basic life support; BMV, bag-mask ventilation; CAB, circulation-airway-breathing; CCO-CPR, chest compression–only cardiopulmonary resuscitation; CoSTR, Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations; CPR, cardiopulmonary resuscitation; CV, compression-to-ventilation; DSED, double sequential external defibrillation; EMS, emergency medical services; EvUp, evidence update; HBV, hepatitis B virus; IHCA, in-hospital cardiac arrest; IQR, interquartile range; OHCA, out-of-hospital cardiac arrest; PAD, public-access defibrillation; PICO, population, intervention, comparator, outcome; RCT, randomized controlled trial; RR, relative risk; SARS, severe acute respiratory syndrome; SCD, sudden cardiac death; SysRev, systematic review; T-CPR, telecommunicator CPR; and VF, ventricular fibrillation.

ADVANCED LIFE SUPPORT

ECPR for Cardiac Arrest (SysRev)

Rationale for Review

ECPR use continues to increase in some centers but is still not widely available. Since the last review of this topic,[105] the task force was aware of 2 new RCTs. This significant addition to the body of evidence prompted the task force to update the SysRev completed for the 2019 CoSTR. The SysRev was registered before initiation (PROSPERO registration CRD42022341077).[106] The full online CoSTR can be found on the ILCOR website.[107]

PICOST

- Population: Adult (age ≥18 years) patients with cardiac arrest in any setting
- Intervention: ECPR including extracorporeal membrane oxygenation (ECMO) or cardiopulmonary bypass during cardiac arrest
- Comparators: Manual or mechanical CPR
- Outcomes: Any clinical outcome
- Study designs: This was an update of the ILCOR SysRev addressing ECPR for cardiac arrest in 2018.[105] New RCTs, non-RCTs, and observational studies (cohort studies and case-control studies) with a control group (patients not receiving ECPR) were included. Ecological studies, case series, case reports, reviews, abstracts, editorials, comments, letters to the editor, and unpublished studies were not included. Studies assessing cost-effectiveness were included for a descriptive overview. Studies exclusively assessing the use of extracorporeal life support for cardiac or respiratory failure after

sustained ROSC were not included. Studies assessing extracorporeal circulation for deep hypothermia (or other conditions) were included only if cardiac arrest was documented.
- Time frame: New studies published between January 1, 2018, and June 21, 2022. All languages were included if there was an English abstract.

Consensus on Science

Because 3 randomized trials[108–110] were identified, observational studies were not considered for the updated consensus on science because of the high risk of bias. A summary of the observational studies is provided in the SysRevs.[105,106]

Key outcomes from the 3 included randomized trials are summarized in Table 4. One trial was stopped early for benefit after 30 patients[108]; 1 trial was stopped early because of slow enrollments after 15 patients[109]; and 1 trial was terminated early because of futility in the primary outcome, although there was an overall signal toward benefit.[110]

The overall certainty of evidence was rated as low because of inconsistency and imprecision and was considered very low for in-hospital cardiac arrest (IHCA) because there were no trials for IHCA. Because of a high degree of heterogeneity between the randomized trials, no meta-analyses were performed.

Prior Treatment Recommendation (2019)

We suggest that ECPR may be considered as a rescue therapy for selected patients with cardiac arrest when conventional CPR is failing in settings in which this can be implemented (weak recommendation, very low–certainty evidence).

2023 Treatment Recommendation

We suggest that ECPR may be considered as a rescue therapy for selected patients with OHCA when conventional CPR is failing to restore spontaneous circulation in settings in which this can be implemented (weak recommendation, low-certainty evidence).

We suggest that ECPR may be considered as a rescue therapy for selected patients with IHCA when conventional CPR is failing to restore spontaneous circulation in settings in which this can be implemented (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[107]

- In making this weak recommendation, we note that this patient population (ie, cardiac arrest for which conventional CPR is failing) has a very high mortality rate. Therefore, the potential for benefit and value of this intervention remains despite the overall low certainty in the evidence.
- The published randomized trials have included highly selected patients for ECPR. The trial by Yannopoulos et al[108] enrolled patients with OHCA with an initial shockable rhythm refractory to at least 3 shocks and randomized patients on hospital arrival. The trials by Hsu et al[109] and Belohlavek et al[110] enrolled patients with OHCA with any initial rhythm and randomized patients in the prehospital setting. In all 3 trials, the intervention was a treatment strategy that included ECPR. The percentages of patients in the intervention group who received ECPR were 80%, 42%, and 66% in the Yannopoulos et al, Hsu et al, and Belohlavek et al trials, respectively. The ECPR strategy in the trials by Yannopoulos et al and Belohlavek et al included immediate access to a catheterization laboratory. Guidelines for clinical practice should ideally apply to populations similar to those enrolled in the trials to date, although randomized trials have not been performed to define the optimal population. For this reason, the findings of individual trials should be interpreted cautiously in the context of the trial setting and population.

Table 4. Key Outcomes by Treatment Group and Absolute Risk Difference for Patients Treated With an ECPR Strategy Compared With Standard Care

Author, year	n	Survival to discharge/30 d, n (%)		ARD (95% CI), %	Favorable functional outcome* at discharge/30 d, n (%)		ARD (95% CI), %	Favorable functional outcome* at 6 mo, n (%)		ARD (95% CI), %
		ECPR strategy	Standard care		ECPR strategy	Standard care		ECPR strategy	Standard care	
Yannopoulos et al,[108] 2020	30	6/14 (43)	1/15 (7)	36 (7.4 to 65)	3/14 (21)	0	21 (0 to 43)	6/14 (43)	0	43 (17 to 69)
Hsu et al,[109] 2021	15	0/12	1/3 (33)	−33 (−87 to 20)	0/12	0/3	0	NA	NA	NA
Belohlavek et al,[110] 2022	264	52/124 (42)	43/132 (33)	9.4 (−2.4 to 21)	38/124 (31)	24/132 (18)	13 (2 to 23)	39/124 (32)	29/132 (22)	10 (−1.3 to 20)

ARD indicates absolute risk difference; ECPR, extracorporeal cardiopulmonary resuscitation; and NA, not applicable.
*Favorable functional outcome defined as a modified Rankin Scale score of 0 to 3 or Cerebral Performance Category 1 or 2.

- We acknowledge that ECPR is a complex intervention that requires considerable resources and training that are not universally available but also acknowledge the value of an intervention that may be successful in individuals for whom usual CPR techniques have failed.

Task Force Knowledge Gaps

- Few, and no large, randomized trials of ECPR compared with standard care
- The optimal patient population who may benefit from ECPR
- Whether subgroups of patients such as those with cardiac arrest related to pregnancy or pulmonary embolism benefit from ECPR
- The optimal time to initiate ECPR in cases of refractory cardiac arrest
- Whether ECPR should be initiated in the prehospital or in-hospital setting
- The optimal techniques for providing safe and timely ECPR
- Optimal methods for implementing ECPR programs, and quality metrics to track implementation success
- The optimal post–cardiac arrest care strategy for patients resuscitated with ECPR
- Population-specific differences in performing ECPR for IHCA and OHCA
- Cost-effectiveness of ECPR

DSED for Cardiac Arrest With Refractory Shockable Rhythm (SysRev)

Rationale for Review

A 2020 SysRev conducted by the ALS Task Force found no evidence of improved outcomes with the use of DSED; however, there was a recognized lack of high-quality data.[111] The recent publication of an RCT prompted an update of the 2020 SysRev (registered on PROSPERO October 6, 2022). The full online CoSTR can be found on the ILCOR website.[112]

PICOST

- Population: Adults in any setting (in hospital or out of hospital) with cardiac arrest and a shockable ventricular fibrillation (VF)/pulseless ventricular tachycardia cardiac arrest rhythm
- Intervention: DSED
- Comparators: Standard defibrillation (SD) strategy
- Outcomes:
  - Critical: Survival to hospital discharge or good neurological survival at discharge or 30 days or at >30 days
  - Important: ROSC and survival to hospital admission
  - Other: Termination of VF/pulseless ventricular tachycardia
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Unpublished studies (eg, conference abstracts, trial protocols) were excluded. All relevant publications in any language were included as long as there was an English abstract.
- Time frame: Literature search for this update included studies published from February 28, 2020, to November 7, 2022.

Consensus on Science

We identified 1 cluster RCT, which included the pilot trial identified in the prior review.[113,114] No new observational studies were identified. The cluster RCT compared DSED and vector change (VC; anteroposterior pad placement) defibrillation with SD (anterolateral pad placement) defibrillation. Therefore, this CoSTR includes the data comparing VC with SD and that comparing DSED with SD. Data were not available for adjusted statistical comparison of DSED with VC because the trial was not designed for that comparison and this post hoc analysis could not be obtained. All calculations of adjusted relative risk (aRR) were adjusted for cluster (cluster randomized trial), age, sex, and receipt of lay rescuer CPR. Unadjusted relative risk and absolute risk difference are provided in the online Grading of GRADE tables, along with the primary adjusted results.[112]

DSED Compared With SD

A single trial[114] including 261 patients with OHCA provides low-certainty evidence (downgraded for risk of bias and imprecision) for improved functional outcome (defined as modified Rankin Scale [mRS] score of 0–2) at hospital discharge with DSED compared with SD (27.4% versus 11.2%; aRR, 2.21 [95% CI, 1.26–3.88]) and improved survival to hospital discharge (30.4% versus 13.3%; aRR, 2.21 [95% CI, 1.33–3.67]). There were also an improved rate of ROSC with DSED compared with SD (46.4% versus 26.5%; aRR, 1.72 [95% CI, 1.22–2.42]) and a higher rate of termination of VF (84% versus 67.6%; aRR, 1.25 [95% CI, 1.09–1.44]).

VC Defibrillation Compared With SD

A single trial[114] including 280 patients provides very low–certainty evidence (downgraded for serious risk of bias and very serious imprecision) of no significant improvement in favorable functional survival at discharge (defined as mRS score of 0–2) from VC compared with SD (16.2% versus 11.2%; aRR, 1.48 [95% CI, 0.81–2.71]) and no significant improvement in ROSC (35.4% versus 26.5%; aRR, 1.39 [95% CI, 0.97–1.99]). There was improved survival to hospital discharge with VC compared with SD (21.7% versus 13.3%; aRR, 2.21 [95% CI, 1.01–2.88]) and a higher rate of termination of VF with VC compared with SD (79.9% versus 67.6%; aRR, 1.18 [95% CI, 1.03–1.36]).

Prior Treatment Recommendation (2020)

We suggest against routine use of dual (or double) sequential defibrillation strategy compared with an SD strategy for cardiac arrest with a shockable rhythm (weak recommendation, very low–certainty evidence).

2023 Treatment Recommendations

We suggest that a DSED strategy (weak recommendation, low-certainty evidence) or a VC defibrillation strategy (weak recommendation, very low–certainty evidence) may be considered for adults with cardiac arrest who remain in VF or pulseless ventricular tachycardia after ≥3 consecutive shocks.

If a DSED strategy is used, we suggest an approach similar to that in the available trial, with a single operator activating the defibrillators in sequence (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[112]

- Current evidence does not permit distinguishing whether either strategy (DSED or VC defibrillation) is superior to the other.
- The task force discussed the importance of ensuring correct pad placement for SD before progressing to DSED or VC defibrillation and agreed with the descriptions of anterolateral pad placement provided in existing guidelines from the AHA and the European Resuscitation Council. These guidelines recommend that defibrillation pads be placed to anatomically encompass the heart (with one pad below the right clavicle, just to the right of the upper sternal border, and the other with the center of the pad in the left midaxillary line) and that adequate contact be made at the pad-skin interface so as to optimize energy delivery.[115]
- Double shocks require the availability of 2 defibrillators, and this has resource implications. The task force noted that DSED is already used by some EMS systems for refractory shockable cardiac arrest and therefore may be easily implemented in some systems. In other systems, this practice could require significant new resource allocation for additional defibrillators or ambulances, and the task force acknowledged that such an increase in resource allocation may not be justified on the basis of a single relatively small study.
- The difference between truly refractory VF (failure to be terminated) and recurrent VF (recurring after successful defibrillation) may not be recognized clinically. Although not currently recommended for use, in the future, "see-through CPR" algorithms (enabling detection of underlying rhythm during CPR) may permit distinguishing patients with incessant refractory VF from recurrent VF after shock delivery and thus better direct electrical versus pharmacological or other therapies.
- The task force discussed the concern that a single smaller-than-planned study leaves significant uncertainty about treatment effect.
- The protocol used in the existing trial, with a single person providing 2 defibrillation shocks in quick succession (but not simultaneously), did not result in any reports of defibrillator damage and therefore is likely the best approach to use currently.
- The importance of not equating 2 sequential shocks with a single higher-energy shock was highlighted.
- Current evidence does not permit distinguishing whether the VC or the double shock using the VC in addition to SD accounts for the observed benefit. The task force had extensive discussions about whether the anteroposterior pad placement or the DSED provided most of the benefit seen.
- Sensitivity analyses included in the available trial did not show a difference in outcomes with DSED when patients were analyzed by treatment received rather than intent to treat (randomization group). Reasons why certain patients received a defibrillation strategy other than that to which they were randomized are not known.

Task Force Knowledge Gaps

- Whether the benefit from DSED seen in this single trial will be replicated in other settings
- Whether DSED is beneficial compared with changing pad placement (VC defibrillation)
- The optimal timing of shock delivery when a DSED strategy is used
- Whether DSED has an effect on health-related quality of life

Calcium During Cardiac Arrest (SysRev)

Rationale for Review

Calcium has not been recommended for routine use during cardiac arrest for many years,[116] but it continues to be given frequently. This topic was prioritized because of the publication of a recent RCT that adds significantly to the available evidence.[117] A SysRev was conducted by members of the ALS Task Force (PROSPERO CRD4202234964).[118] The SysRev included literature on adults and children. The evidence for adults was considered for this CoSTR. The full online CoSTR can be found on the ILCOR website.[119]

PICOST

- Population: Adults with cardiac arrest in any setting
- Intervention: Administration of calcium (intravenous or intraosseous) during cardiac arrest
- Comparators: No administration of calcium during cardiac arrest

- Outcomes: Any clinical outcome, including ROSC, short-term survival and neurological outcomes (eg, hospital discharge, 28 days, 30 days, and 1 month), and long-term survival and neurological outcomes (eg, 3 months, 6 months, 1 year)
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) with a control group were eligible for inclusion. Ecological studies, case series, case reports, reviews, abstracts, editorials, comments, letters to the editor, and unpublished studies were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was conducted on July 8, 2022, and updated on September 31, 2022.

Consensus on Science

Three RCTs were identified, so because of the critical risk of bias inherent in the observational studies, only data from the 3 RCTs (one of which resulted in an additional article reporting long-term outcomes) were considered.[117,120–122] The more recent and largest trial was stopped early because of concern for harm from the intervention. Key results from these trials are presented in Table 5. There were no statistically significant differences seen in any of the trials, with the exception of survival with favorable functional outcome at 90 days and 1 year in the more recent trial, with results suggesting worse outcome with calcium in both cases.[117,122] All results are reported in full in the online CoSTR.[119] Calcium has not been studied in the IHCA setting. Therefore, the certainty of evidence for adult IHCA was additionally downgraded for indirectness.

Prior Treatment Recommendation (2010)

Routine administration of calcium for treatment of IHCA and OHCA is not recommended.

2023 Treatment Recommendations

We recommend against routine administration of calcium for the treatment of OHCA in adults (strong recommendation, moderate-certainty evidence).

We suggest against routine administration of calcium for the treatment of IHCA in adults (weak recommendation, low-certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[119] Key points include the following:

- This CoSTR and its SysRev focus on the routine administration of calcium during cardiac arrest in adults.
- We did not identify any RCTs comparing calcium administration with no calcium administration during IHCA or for specific patient groups such as those with hyperkalemic cardiac arrest.
- The trial by Vallentin et al[117] was stopped early on the basis of suggestions of harm in a preplanned interim analysis, which could have increased the risk of effect size overestimation.
- The risk of harm with calcium administration may depend on the scenario in which the intervention is performed.
- The effect of calcium administration remains unknown for adults in cardiac arrest from special circumstances such as hyperkalemia, wide QRS interval on ECG, hypocalcemia, hypermagnesemia, calcium channel blocker overdose, or hemorrhage. Existing trials provide insufficient data on these subgroups to be able to evaluate this.
- Only small trials or observational studies have attempted to stratify on the basis of initial rhythm or potassium values, and they have been limited by critical risk of bias because of confounding.

Task Force Knowledge Gaps

- No RCTs have evaluated calcium during IHCA.
- The effect of calcium during cardiac arrest from special circumstances such as hyperkalemia, wide QRS interval on ECG, hypocalcemia, hypermagnesemia, calcium channel blocker overdose, or hemorrhage
- The mechanism of harm from calcium during cardiac arrest

Prognostication of Favorable Neurological Outcome (SysRev Adolopment)

Rationale for Review

This SysRev of prognostication after cardiac arrest (PROSPERO: CRD 420 1914 1169) was conducted by a SysRev team with involvement of content experts from the ILCOR ALS Task Force and consisted of 2 parts. The first part addressed prediction of poor neurological outcome and provided evidence for the 2020 CoSTR.[123,124] The second part addressed prediction of favorable neurological outcome.[125] Because the SysRev on prognostication of favorable outcome was recent and met ILCOR criteria for being of sufficient quality, the task force deemed it appropriate for adolopment. An updated search including the dates October 31, 2021, through May 20, 2022, was conducted to identify any articles published since the search for the original SysRev. This evidence was divided into several sections: GCS motor score, imaging, biomarkers, use of EEG, and SSEP. These are summarized later. Sensitivity and specificity of each modality for the prediction of favorable neurological outcome are reported for included studies. In this case, sensitivity refers to the percentage of patients with a favorable outcome who will have a positive (meaning favorable, as in a low or normal biomarker level or normal head computed tomography [CT] or EEG) test, and specificity

Table 5. Selected Outcomes and Certainty of Evidence for Included Randomized Clinical Trials of Calcium During OHCA

Study, year	n	ROSC, n (%)		Survival at 30, 90, and 180 d, n (%)*		Survival at 1 y, n (%)		Favorable neurological outcome at 1 y, n (%)		Certainty of evidence
		Calcium	Control	Calcium	Control	Calcium	Control	Calcium	Control	
Stueven et al[120] (PEA), 1985	90	8/48 (16.7)	2/42 (4.8)	NR		NR		NR		Very low†
		RR, 3.5 (95% CI, 0.79–15.58)								
Stueven et al[121] (asystole), 1985	73	3/39 (7.7)	1/34 (2.9)	0 in both groups at discharge		NR		NR		Very low†
		RR, 2.43 (95% CI, 0.26–22.31)								
Vallentin et al,[117] 2021, and Vallentin et al,[122] 2022	391	37/193 (19)	53/198 (27)	10/193 (5.2)	18/198 (9.1)	9/193 (4.7)	18/198 (9.1)	7/193 (3.6)	17/198 (8.6)	Moderate‡
		RR, 0.72 (95% CI, 0.49–1.03)		RR, 0.57 (95% CI, 0.27–1.18)		RR, 0.51 (95% CI, 0.24–1.09)		RR, 0.42 (95% CI, 0.18–0.97)		

NR indicates not reported; OHCA, out-of-hospital cardiac arrest; PEA, pulseless electrical activity; ROSC, return of spontaneous circulation; and RR, relative risk.
*Survival at all 3 time points was the same in the Vallentin et al study.
†Downgraded for risk of bias and very serious imprecision.
‡Downgraded for imprecision.

refers to the percentage of patients with an unfavorable outcome who will have a negative (meaning unfavorable, as in a high biomarker level or abnormal head CT or EEG) test. None of the included predictors had the <1% rate of falsely optimistic prediction that most clinicians would consider appropriate according to a survey conducted in 2019.[126] However, the panel considered that achieving a 0% false-positive rate (FPR) with narrow CIs when predicting good outcome is less important than when predicting poor outcome because good outcome predictors are not used to withdraw life-sustaining treatment.

Except when noted, all PICOST questions for neuroprognostication used the same PICOSTs. These are therefore listed here once and not repeated. Similarly, certainty of evidence was very low certainty for all neuroprognostication modalities included. Reasons for this are detailed in the individual online CoSTRs and not included here.

Population, Comparator, Outcomes, Study Design, and Time Frame for All Neuroprognostication PICOSTs

- Population: Adults (age ≥16 years) who are comatose after resuscitation from cardiac arrest (either in hospital or out of hospital), regardless of target temperature
- Comparators: None
- Outcomes: Prediction of good neurological outcome defined as Cerebral Performance Category (CPC) 1 or 2 or mRS score of 1 to 3 at hospital discharge or 1 month or later
- Study designs: Prognostic accuracy studies for which the 2×2 contingency table (ie, the number of true/false negatives and positives for prediction of poor outcome) was reported or for which those variables could be calculated from reported data were eligible for inclusion. Unpublished studies, reviews, case reports, case series, studies including <10 patients, letters, editorials, conference abstracts, and studies published in abstract form were excluded.
- Time frame: The original SysRev search was conducted on October 31, 2021, and included studies dating from 2001. The search was updated on May 20, 2022.

Use of the GCS Motor Score for Prediction of Good Neurological Outcome After Cardiac Arrest (SysRev Adolopment)

Intervention

GCS motor score evaluated within 4 days after cardiac arrest.

Consensus on Science

The full online CoSTR can be found on the ILCOR website.[127]

The original SysRev identified 2 observational studies on the prediction of good neurological outcome using the GCS motor score (scored from 1–6, with higher scores being more favorable) on admission and within the first 4 days after cardiac arrest. No new studies were identified in the updated search. In 1 study[128] including 342 patients with OHCA, a GCS motor score >3 on day 4 after cardiac arrest predicted favorable outcome at 6 months with a specificity of 84% (95% CI, 79%–88%) and a sensitivity of 77% (95% CI, 67%–85%), and a GCS motor score 3 to 5 on day 4 predicted favorable outcome with 72% (95% CI, 66%–77%) specificity and 96% (95% CI, 93%–97%) sensitivity. In 1 study[129] including 302 patients with OHCA, a GCS motor score of 4 to 5 evaluated on intensive care unit (ICU) admission after cardiac arrest predicted a favorable outcome at

3 months with a specificity of 98% (95% CI, 93%–99%) and sensitivity of 12% (95% CI, 7%–17%).

Prior Treatment Recommendations

None (new recommendation)

2023 Treatment Recommendation

We suggest assessing the GCS motor score in the first 4 days after cardiac arrest to identify patients with a score >3, which may indicate an increased likelihood of favorable outcome (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[127] Key points include the following:

- Sedation and pain medication may influence the assessment of the GCS motor score. Waiting time after stopping such medications to achieve a reliable test result varies.
- The assessment of the GCS motor score is an integral part of the identification of those unconscious patients who should undergo prognostication tests after cardiac arrest. Using the GCS motor score to identify those with a better motor response is not likely to have undesirable effects.
- Any possible withdrawal of life-sustaining therapies in post–cardiac arrest patients should be undertaken only by using several prognostication modalities according to the 2020 CoSTR on the prediction of poor outcome, which includes distinct recommendations.[123,124]

Task Force Knowledge Gaps

- Utility of GCS in post–cardiac arrest patients at various time points
- Utility of the GCS motor score for patients with IHCA and those with a noncardiac cause of the arrest
- How GCS motor score compares with other means of assessing prognosis, including studies assessing costs and cost-effectiveness
- Value of GCS motor score in combination with other prognostic tests
- Whether there is significant interrater variability between different health care professionals assessing the GCS motor score in post–cardiac arrest patients

Imaging for Prediction of Good Neurological Outcome (SysRev Adolopment)

Intervention

Imaging studies assessed within 1 week after cardiac arrest.

Outcomes

CPC 1 to 3 or mRS score of 0 to 4 was accepted as an indirect outcome, in addition to the CPC 1 or 2 or mRS score of 0 to 3 used for this and other prognostication PICOSTs.

Consensus on Science

The full online CoSTR can be found on the ILCOR website.[130]

For the outcome of favorable neurological outcome, we identified 6 studies.[131–136] Because of considerable heterogeneity between the studies, no meta-analysis was performed. Favorable outcome was defined as a CPC 1 or 2 or mRS score of 0 to 3 in most studies. In 1 study,[135] good neurological outcome was measured as CPC 1 to 3 instead of 1 or 2.

Brain CT

A single study was identified by assessing the use of brain CT for prognostication of favorable neurological outcome. Key findings are summarized in Table 6, and details of the CT assessment techniques are provided in the online CoSTR and the SysRev.[125]

Brain Magnetic Resonance Imaging

Five observational studies were identified that examined the use of magnetic resonance imaging (MRI) for prognostication of good neurological outcome.[132–136] Time points of imaging ranged from 3.1 hours after ROSC to 8 days. Key study findings are summarized in Table 7.

Prior Treatment Recommendations

None (new recommendation)

2023 Treatment Recommendations

We suggest using the absence of diffusion restriction on MRI between 72 hours and 7 days after ROSC, in

Table 6. Gray-White Matter Ratio, Quantitative Regional Abnormality, and ASPECTS-b Using Brain CT: Sensitivity and Specificity for Favorable Neurological Outcome at 1 Month in a Single Study[131] of CT at 1 to 3 Hours After ROSC

CT variable	n	Timing after ROSC, min	Sensitivity (95% CI), %	Specificity (95% CI), %
GWR >1.25	67	124.5±59.9	25 (8.7–49.1)	77 (62.0–87.7)
QRA ≤5	67	124.5±59.9	25 (8.7–49.1)	77 (62.0–87.7)
ASPECTS-b ≥15	67	124.5±59.9	75 (50.9–91.3)	89 (76.9–96.0)

ASPECTS-b indicates Alberta Stroke Program Early CT Score; CT, computed tomography; GWR, gray-white matter ratio; QRA, quantitative regional abnormality; and ROSC, return of spontaneous circulation.

Adapted from Sandroni et al.[125] This is an Open Access article under the CC BY-NC 4.0 license.

Table 7. Sensitivity and Specificity of Findings on MRI–Including Diffusion-Weighted Imaging, Fluid-Attenuated Inversion Recovery, T2-Weighted Gradient-Recalled Echo, and Average Apparent Diffusion Coefficient –for Prediction of Favorable Neurological Outcome* at 6 Months

Study, y	n	MRI measure	Timing after ROSC	Sensitivity (95% CI), %	Specificity (95% CI), %
Park et al,[134] 2020	36	Absence of cortical necrosis	3.1 h (2.4–4)	100.0 (86.7–100.0)	60.0 (32.3–83.7)
Park et al,[134] 2020	36	Absence of cortical necrosis	77.6 h (75.9–80)	100.0 (86.7–100.0)	93.3 (68.1–99.8)
Oh et al,[133] 2019	134	No diffusion restriction in cortex or deep gray matter	After rewarming	72.2 (54.8–85.8)	94.9 (88.5–98.3)
Oh et al,[133] 2019	134	No or single diffusion restriction cortex or deep gray matter	After rewarming	94.4 (81.3–99.3)	91.8 (84.5–96.4)
Jang et al,[132] 2019	39	Absence of restricted diffusion	77.6 h (75.9–80)	91.7 (61.5–99.8)	92.6 (75.7–99.1)
Mlynash et al,[135] 2010†	33	No DWI or FLAIR lesions in cortex	≤8 d	77.8 (52.4–93.6)	80.0 (51.9–95.7)
Mlynash et al,[135] 2010†	33	No DWI or FLAIR lesions in deep gray nuclei	≤8 d	50.0 (26.0–74.0)	86.7 (59.5–98.3)
Mlynash et al,[135] 2010†	33	No DWI or FLAIR lesions in cerebellum and pons	≤8 d	100.0 (84.7–100.0)	20.0 (4.3–48.1)
Jang et al,[132] 2019	39	Summary GRE score of 0		75.0 (42.8–94.5)	100.0 (89.5–100.0)
Wouters et al,[136] 2021	58	Average ADC >931×10^{-6} mm^2/s	5 d (IQR 4–6 d)	100.0 (86.0–100.0)	38.0 (23.0–58.0)

ADC indicates apparent diffusion coefficient; DWI, diffusion-weighted imaging; FLAIR, fluid-attenuated inversion recovery; GRE, gradient-recalled echo; IQR, interquartile range; MRI, magnetic resonance imaging; and ROSC, return of spontaneous circulation.

*Defined as Cerebral Performance Category 1 or 2 or modified Rankin Scale score of 0 to 3.

†Favorable neurological outcome defined as Cerebral Performance Category 1 to 3 for this study.

combination with other tests, for predicting good neurological outcome of adults who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

We suggest against using gray-white matter ratio (GWR), quantitative regional abnormality, and Alberta Stroke Program Early CT Score on brain CT to predict good neurological outcome in patients who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

We suggest against using apparent diffusion coefficient on brain MRI to predict good neurological outcome in patients who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

We suggest against using gradient-recalled echo on brain MRI to predict good neurological outcome in patients who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[130] Key points include the following:

- Evidence from 5 studies consistently suggests that the absence of visible cytotoxic edema, assessed as the absence of cortical diffusion-weighted imaging changes on brain MRI, predicts good neurological outcome with high specificity at ≥72 hours after cardiac arrest.
- Apparent diffusion coefficient enables quantification of the diffusion changes on brain MRI. However, the evidence is limited to 1 study, and no apparent diffusion coefficient threshold for prediction of good neurological outcome has been established.
- Evidence showing that a high GWR, a low quantitative regional attenuation score, or a high Alberta Stroke Program Early CT score predicts good neurological outcome after cardiac arrest is limited to 1 study. There is considerable heterogeneity in measurement techniques (sites and calculation methods) for GWR in the medical literature.
- Evidence for GWR and gradient-recalled echo was limited to small, single-center studies.
- Lack of blinding was a limitation in all included studies.
- Any possible withdrawal of life-sustaining therapies in post–cardiac arrest patients should be undertaken only by using several prognostication modalities according to the 2020 CoSTR on the prediction of poor outcome, which includes distinct recommendations.[123,124]

Task Force Knowledge Gaps

- Whether there is a consistent GWR threshold for predicting good neurological outcome after cardiac arrest
- Standardization of the methods for GWR calculation, apparent diffusion coefficient calculation, and the criteria for defining an MRI as normal
- The optimal timing for prognostication using brain CT after cardiac arrest
- The value of serial brain CT after cardiac arrest to predict good neurological outcome

Use of Brain Injury Biomarkers for the Prediction of Good Outcome After Cardiac Arrest (SysRev Adolopment)

Intervention

A normal or a low value for one of the following brain injury biomarkers: neuron-specific enolase (NSE), S100 calcium-binding protein B (S100B), neurofilament light chain (NfL), tau, glial fibrillary acid protein, or ubiquitin carboxy-terminal hydrolase-1

Consensus on Science

The full online CoSTR can be found on the ILCOR website.[137] Six observational studies were identified on biomarkers for prediction of good neurological outcome, 4 studies[138–141] in the initial SysRev[125] and 2 studies[142,143] in the updated search. Because of considerable heterogeneity between studies, no meta-analyses were performed.

Neuron-Specific Enolase

NSE was investigated in 4 observational studies, including a total of 2141 patients.[138–140,142] Sample acquisition ranged from 24 to 72 hours. Key results are presented in Table 8.

S100B, Glial Fibrillary Acid Protein, Tau Protein, NfL, and Ubiquitin Carboxy-Terminal Hydrolase-1

Several studies were identified for other serum biomarkers to predict favorable neurological outcome. Thresholds varied across studies in many cases, as did sensitivity and specificity. An overview of findings, grouped by biomarker, is provided in Table 9. For full details, see the online CoSTR.[137]

Prior Treatment Recommendations

None (new recommendation)

2023 Treatment Recommendations

We suggest using normal NSE (<17 μg/L) within 72 hours after ROSC, in combination with other tests, for predicting favorable neurological outcome in adults who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

We suggest against using serum levels of glial fibrillary acidic protein, serum tau protein, or NfL in clinical practice for predicting favorable neurological outcome in adults who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[137] Key points include the following:

- The best evidence is for NSE, given the number of patients included in trials and the similar thresholds used to determine a normal value across studies.
- Evidence for the accuracy of the biomarkers S100B, NfL, glial fibrillary acid protein, tau, and ubiquitin carboxy-terminal hydrolase-1 is inconsistent. NfL may be more accurate, but there are few data on feasibility of measuring these novel biomarkers in regular clinical practice because all analyses have included thawed samples measured later in highly specialized laboratories. Threshold levels for predicting a good functional outcome have also varied considerably.
- Any possible withdrawal of life-sustaining therapies in patients with cardiac arrest should be undertaken only by using several prognostication modalities according to the 2020 CoSTR on the prediction of poor outcome, which includes distinct recommendations.[123,124]

Task Force Knowledge Gaps

- The utility of biomarkers in patients with IHCA and those with a noncardiac cause of arrest

Table 8. Sensitivity and Specificity of NSE for Prediction of Favorable Neurological Outcome*

Study, y	n	Threshold value, μg/L	Time of acquisition, h	Sensitivity (95% CI), %	Specificity (95% CI), %
Zellner et al,[138] 2013	103	<17	24	26 (15–40)	89 (77–96)
	84		48	41 (25–58)	89 (77–97)
Moseby-Knappe et al,[139] 2021	650	≤17	24	46 (41–52)	85 (81–89)
	614		48	58 (52–63)	84 (79–88)
	572		72	75 (70–80)	80 (75–85)
Streitberger et al,[140] 2017†	1053	≤17	72	33 (29–37)	97 (95–98)
Wihersaari al,[142] 2022‡	248	≤17	48	90 (85–95)	54 (44–64)

NSE indicates neuron-specific enolase.
*Defined as Cerebral Performance Category 1 or 2 or modified Rankin Scale score of 0 to 3 at 6 months.
†Favorable neurological outcome defined as Cerebral Performance Category 1 to 3 at intensive care unit discharge in this study.
‡Outcome measured at 12 months in this study.
Adapted from Sandroni et al.[125] This is an Open Access article under the CC BY-NC 4.0 license.

Table 9. Overview of Studies on Blood S100B, Glial Fibrillary Acid Protein, Tau Protein, NfL, and Ubiquitin Carboxyl-Terminal Hydrolase-L1 to Predict Favorable Neurological Outcome at 6 Months

Study, y	n	Threshold value	Time of acquisition, h	Sensitivity (95% CI), %	Specificity (95% CI), %
S100B					
Zellner et al,[138] 2013	114	<0.61 µg/L	Admission	31 (20–45)	89 (78–96)
	110	<0.12 µg/L	24	37 (24–51)	89 (78–96)
Moseby-Knappe et al,[139] 2021	649	<0.105 µg/L	24	69 (64–74)	74 (69–79)
NfL					
Moseby-Knappe et al,[139] 2021	692	<55 pg/mL	24	26 (15–40)	89 (77–96)
	658		48	41 (25–58)	89 (77–97)
	608		72	51 (45–56)	97 (94–98)
Wihersaari et al,[141] 2021	107	<30 pg/mL	24	79 (67–88)	100 (92–100)
	109		48	74 (62–84)	100 (92–100)
	103	<27 pg/mL	72	67 (56–79)	100 (91–100)
Wihersaari et al,[142] 2022	227	≤55 pg/mL	24	74 (66–82)	86 (80–92)
	180		48	67 (58–77)	87 (80–95)
GFAP					
Moseby-Knappe et al,[139] 2021	689	<22 pg/mL	24	41 (36–46)	97 (94–98)
	654		48	35 (30–41)	97 (95–99)
	599		72	44 (39–50)	95 (92–97)
Humaloja et al,[143] 2022	108	<210 pg/mL	48	100 (100–100)	43 (32–54)
	108	<439 pg/mL	48	94 (87–100)	75 (65–85)
Serum tau protein					
Moseby-Knappe et al,[139] 2021	694	≤1.55 pg/mL	24	28 (24–33)	94 (90–96)
	661		48	35 (30–41)	97 (95–99)
	611		72	44 (39–50)	95 (92–97)
Humaloja et al,[143] 2022	109	≤3.28 pg/mL	48	94 (87–100)	53 (42–65)
	105	≤2.1 pg/mL	72	100 (100–100)	21 (12–31)
	105	≤3.37 pg/mL	72	94 (86–100)	52 (40–64)
UCH-L1					
Moseby-Knappe et al,[139] 2021	693	<327 pg/mL	24	64 (58–69)	85 (81–88)
	663		48	74 (69–78)	82 (77–86)
	610		72	88 (84–91)	70 (65–76)

GFAP indicates glial fibrillary acid protein; NfL, neurofilament light chain; S100B, S100 calcium-binding protein B; and UCH-L1, ubiquitin carboxyl-terminal hydrolase-L1.

- The use of NSE in patients with variable degrees of hemolysis
- The accuracy of biomarkers when used together with other means of predicting a good outcome such as examination, imaging, EEG, SSEP, and other biomarkers
- The cost-effectiveness of the use of biomarkers for predicting outcome
- Whether the results of NSE measurements are consistent even if there is deviation from the recommended assessment time point
- The optimal thresholds for biomarkers for prediction of favorable outcome

EEG for Prediction of Good Neurological Outcome (SysRev Adolopment)

Intervention

Various EEG modalities assessed within 1 week after cardiac arrest

Outcomes

CPC 1 to 3 or mRS score of 0 to 4 was accepted as an indirect outcome, in addition to the CPC 1 or 2 or mRS score of 0 to 3 used for this and other prognostication PICOSTs.

Consensus on Science

The full online CoSTR can be found on the ILCOR website.[144]

The original SysRev[125] identified 24 studies. Of these, 15 investigated EEG, 5 investigated reduced-montage or amplitude-integrated EEG, and 4 investigated EEG-derived indices such as bispectral index (BIS). The updated review identified no additional studies meeting inclusion criteria. Several studies did not report the use of medications that can affect EEG background continuity and voltage. All except 3 studies on EEG adopted the 2012 American Clinical Neurophysiology Society (ACNS) terminology. Sensitivity and specificity for all included EEG patterns, as well as timing of acquisition, are detailed for every included study in tables in the associated SysRev,[125] as well as being detailed in the online CoSTR. An overview of key results is provided here.

Continuous or Nearly Continuous EEG Patterns (ACNS Defined)

Twelve studies investigated the ability of a favorable EEG pattern during the first 5 days after ROSC to predict good neurological outcome.[145–156] All studies used the ACNS terminology to describe the EEG patterns. A favorable EEG pattern was defined as a continuous or nearly continuous background without superimposed abundant or generalized periodic discharges or seizures. The criteria for both the background and the superimposed discharges varied slightly across studies (refer to the online CoSTR).[144]

Results of the 6 studies evaluating continuous or nearly continuous, normal-voltage background with no abundant or generalized periodic discharges or seizures[145,146,151–153,155] are presented in Table 10.

Four of the 12 EEG studies[148–150,154] used less-restrictive voltage criteria, including not only a continuous or nearly continuous normal-voltage EEG background but also a low-voltage background among the favorable EEG patterns. Results are presented in Table 11.

Two of the 12 EEG studies used a less-restrictive continuity criteria, including not only a continuous or nearly continuous normal-voltage EEG background but also a discontinuous normal-voltage EEG background. Results of these studies are summarized in Table 12.[147,156]

Other EEG Patterns or Grading Scales

A heterogeneous group of EEG patterns were described as favorable in 3 studies that did not use the ACNS terminology.[157–159] None of these studies excluded EEGs with superimposed discharges from favorable patterns. All 3 studies assessed EEGs within ≈24 to 48 hours after cardiac arrest, and the specificities to predict good outcome ranged between 68% (95% CI, 55.3%–79.4%) and 91% (95% CI, 80%–97%; sensitivities from 75% [95% CI, 42.8%–94.5%] to 96% [95% CI, 78.9%–99.9%]). Specificity was lower for later assessments.

EEG: Continuous Background Assessed Through Reduced-Montage or Amplitude-Integrated EEG

Five studies[132,160–163] investigated the predictive value of a continuous normal-voltage background using amplitude-integrated EEG[132,161] or original EEG with reduced electrode montages[160,162] at a time ranging from 6 to 72 hours after ROSC. Results are summarized in Table 13.

Table 10. Continuous or Nearly Continuous Normal-Voltage EEG With No Abundant/Generalized Periodic Discharges or Seizures for Prediction of Favorable Neurological Outcome

Study, y	n	Note	Timing, h	Outcome timing, mo	Sensitivity (95% CI), %	Specificity (95% CI), %
Admiraal et al,[145] 2019	66	1	12	6	63.2 (46.0–78.2)	82.1 (63.1–93.9)
Admiraal et al,[145] 2019	120		24	6	84.0 (73.7–91.4)	66.7 (54.0–77.8)
Duez et al,[151] 2019	44	2	24	6	38.8 (28.4–50.0)	100.0 (91.8–100.0)
Duez et al,[151] 2019	103		48	6	45.8 (25.6–67.2)	90.0 (68.3–98.8)
Westhall et al,[155] 2016	207		77 (53–102)	6	29.6 (13.8–50.2)	100.0 (96.1–100.0)
Backman et al,[146] 2018	103	3	76 (62–104)	6	77.3 (65.3–86.7)	80.1 (72.6–86.4)
Westhall et al,[155] 2016	120		77 (53–102)	6	48.1 (28.7–68.1)	98.7 (92.9–100.0)
Sondag et al,[153] 2017	248	4	12	6	84.0 (73.7–91.4)	66.7 (54.0–77.8)
Duez et al,[151] 2019	120		24	6	51.2 (42.0–60.3)	88.0 (81.0–93.1)
Hofmeijer et al,[152] 2015	230		24	6	56.5 (45.3–67.2)	97.1 (85.1–99.9)
Duez et al,[151] 2019	44		48	6	77.8 (69.2–84.9)	80.5 (72.0–87.4)
Hofmeijer et al,[152] 2015	187		48	6	62.5 (40.6–81.2)	80.0 (56.3–94.3)
Hofmeijer et al,[152] 2015	97		72	6	95.7 (89.5–98.8)	52.7 (42.1–63.1)

ACNS indicates American Clinical Neurophysiology Society; and EEG, electroencephalogram.

Notes: 1, Continuous or nearly continuous, normal voltage, without unequivocal electrographic seizures, or abundant (>50%) periodic discharges or abundant spike-wave (ACNS). 2, As 1 plus no reversed anteroposterior gradient plus reactive. 3, As 1 plus no reversed anteroposterior gradient. 4, Continuous, either diffusely slowed (dominant frequency <8 Hz) or normal (dominant frequency ≥8 Hz), with no evolving seizures or generalized periodic discharges.

Table 11. Continuous or Nearly Continuous Normal- or Low-Voltage EEG for Prediction of Favorable Neurological Outcome

Study, y	n	Note	Timing, h	Outcome timing, mo	Sensitivity (95% CI), %	Specificity (95% CI), %
Carrai et al,[149] 2021	41	1	<6	6	70.6 (44.0–89.7)	95.8 (78.9–99.9)
Carrai et al,[148] 2016	38		6–12	6	90.9 (58.7–99.8)	96.3 (81.0–99.9)
Scarpino et al,[150] 2021	218		12	6	56.5 (45.3–67.2)	97.7 (93.5–99.5)
Carrai et al,[148] 2016	65		18–24	6	100.0 (85.4–100.0)	87.0 (73.7–95.1)
Rossetti et al,[154] 2017	357	2	≤48	6	76.1 (69.2–82.1)	87.6 (81.8–92.0)
Rossetti et al,[154] 2017	357		48–72	3	90.6 (85.3–94.4)	82.5 (76.1–87.8)
Carrai et al,[148] 2016	64	1		6	100.0 (77.9–100.0)	82.7 (69.7–91.8)

EEG indicates electroencephalogram.

Notes: 1, Continuous, normal, or low voltage, no epileptiform discharges. 2, Continuous, normal, or low voltage, reactive, no epileptiform discharges.

EEG-Derived Indices

One study[164] of 54 patients reported that a cerebral recovery index >0.57 at 18 hours or 0.69 at 24 hours predicted favorable neurological outcome at 6 months with 100% (95% CI, 89.5%–100%) specificity (sensitivities, 65% [95% CI, 44.3%–82.8%] and 26% [95% CI, 11.1%–46.3%], respectively).

Three studies including 201 patients evaluated the predictive value of BIS.[165–167] In 2 studies,[165,166] a BIS value >21 at 1 to 3 hours after ROSC or 24 at 3 to 6 hours after ROSC predicted good neurological outcome with 94% (95% CI, 79.8%–99.3%) and 86% (95% CI, 73.3%–94.2%) specificity, respectively (sensitivities, 88% [95% CI, 61.7%–98.4%] and 94% [95% CI, 83.1%–98.7%]). In 1 study,[167] specificity increased from 41% (95% CI, 25.6%–56.7%) with a BIS of 30 to 92.9% [95% CI, 80.5%–98.5%] with a BIS of 60. Sensitivities decreased from 95% (95% CI, 75.1%–99.9%) to 20% (95% CI, 5.7%–43.7%) when the BIS of 60 was used.

Prior Treatment Recommendations

None (new recommendation)

2023 Treatment Recommendations

We suggest using a continuous or nearly continuous normal-voltage EEG background without periodic discharges or seizures within 72 hours from ROSC in combination with other indices to predict good outcome in patients who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

There is insufficient evidence to recommend for or against using a low-voltage or a discontinuous EEG background on days 0 to 5 from ROSC to predict good neurological outcome after cardiac arrest (weak recommendation, very low–certainty evidence).

We suggest against using heterogeneous, non–ACNS-defined favorable EEG patterns to predict good neurological outcome after cardiac arrest (weak recommendation, very low–certainty evidence).

We suggest against the use of other EEG metrics, including reduced montage or amplitude-integrated EEG, BIS, or EEG-derived indices, to predict good outcome in patients who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

We suggest that the ACNS terminology be used to classify the EEG patterns used for prognostication (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[144] Key points include the following:

- In making the recommendation in favor of a continuous or nearly continuous, normal-voltage EEG background without seizures or abundant or generalized periodic discharges as a predictor of good

Table 12. Continuous, Nearly Continuous, or Discontinuous Normal-Voltage EEG Background for Prediction of Favorable Neurological Outcome

Study, y	n	Note	Timing	Outcome timing	Sensitivity (95% CI), %	Specificity (95% CI), %
Sivaraju et al,[156] 2015	89	1	≤72 h	Hospital discharge	71.9 (53.3–86.3)	96.5 (87.9–99.6)
Sivaraju et al,[156] 2015	89	2		Hospital discharge	100.0 (88.7–100.0)	84.4 (73.1–92.2)
Beretta et al,[147] 2019	166	3	0–5 d	6 mo	77.1 (65.6–86.3)	77.1 (67.4–85)

EEG indicates electroencephalogram.

Notes: 1, Continuous, nearly continuous, or discontinuous, normal voltage, with no epileptiform patterns. 2, As 1 but with any of periodic discharges, rhythmic delta activity, spike-and-wave, sharp-and-wave, or sporadic epileptiform discharges (normal voltage plus). 3, Continuous or reactive, normal-voltage EEG background with no episodes of status epilepticus or generalized periodic discharges.

Table 13. Continuous or Discontinuous: Reduced-Montage or Amplitude-Integrated EEG to Predict Favorable Neurological Outcome at 6 Months or Hospital Discharge

Study, y	n	Timing, h	Outcome timing	Sensitivity (95% CI), %	Specificity (95% CI), %
Wennervirta et al,[160] 2009	30	<24	6 mo	66.7 (43.0–85.4)	55.6 (21.2–86.3)
		24–48		95.2 (76.2–99.9)	66.7 (29.9–92.5)
Jang et al,[132] 2019	39	≤72	6 mo	100.0 (77.9–100.0)	85.2 (66.3–95.8)
Oh et al,[161] 2013	55	≤72	Hospital discharge	57.1 (37.2–75.5)	96.3 (81.0–99.9)
Rundgren et al,[162] 2010	93	8 (5–14)	6 mo	52.7 (38.8–66.3)	92.1 (78.6–98.3)
	95	24–48		94.7 (85.4–98.9)	78.9 (62.7–90.4)
Eertmans et al,[163] 2019	60	6–12	6 mo	54.8 (36.0–72.7)	79.3 (60.3–92.0)
	57	18–24		67.9 (47.6–84.1)	79.3 (60.3–92.0)
	56	36–48		85.7 (67.3–96.0)	78.6 (59.0–91.7)

EEG indicates electroencephalogram.
Adapted from Sandroni et al.[125] This is an Open Access article under the CC BY-NC 4.0 license.

neurological outcome in patients who are comatose after cardiac arrest, the task force members considered the consistency of the evidence (12 studies, mostly with >80% specificity and >50% sensitivity) and the consistency of the definition made using ACNS or ACNS-compatible terminology.

- The background definition was consistent in 6 of these studies. Although the criteria for periodic discharges varied slightly within this subgroup, this did not affect the prediction accuracy.
- Evidence from the remaining 6 studies confirmed the ability of a continuous or nearly continuous, normal-voltage EEG background without seizures or discharges to predict good neurological outcome. These studies also included a low-voltage or discontinuous EEG background among the "favorable" EEG patterns. These patterns are farther from normal than a continuous or nearly continuous background, and their accuracy could not be assessed separately. The ILCOR task force considered the evidence supporting these patterns insufficient for recommending their use.
- The remaining studies on EEG used definitions of favorable patterns that did not comply with the ACNS terminology and were highly heterogeneous.
- Lack of blinding is a limitation of studies that use EEG data.
- In recommending against using amplitude-integrated EEG or EEG-derived indices such as BIS or cerebral recovery index, the panel considered that these techniques do not allow or allow only a limited morphological assessment of the original EEG signal. Moreover, the evidence was limited to few studies (only 1 study for cerebral recovery index).
- Any possible withdrawal of life-sustaining therapies in post–cardiac arrest patients should be undertaken only by using several prognostication modalities according to the 2020 CoSTR on the prediction of poor outcome, which includes distinct recommendations.[123,124]

Task Force Knowledge Gaps

- The effects of sedation and systemic organ dysfunction on the predictive value of the EEG background
- The value of low-voltage background and discontinuous reactive/normal-voltage background
- The value of EEG reactivity for predicting good outcome using standardized stimulation and assessment
- Which aspect of periodic discharges (distribution, morphology, prevalence) has greatest importance in affecting the prognosis of a favorable EEG pattern
- The value of dominant EEG rhythms (eg, theta) in prognostication after cardiac arrest
- The predictive value of favorable EEG patterns defined according to the 2021 ACNS definitions, although the 2012 definitions for features used for predicting a good outcome are a little different from the 2021 definitions

SSEPs for Prediction of Good Neurological Outcome (SysRev Adolopment)

Intervention

SSEP N20 wave amplitude assessed within 1 week from cardiac arrest

Outcomes

CPC 1 to 3 or mRS score of 0 to 4 was accepted as an indirect outcome, in addition to the CPC 1 or 2 or mRS score of 0 to 3 used for this and other prognostication PICOSTs.

Consensus on Science

Complete results, including details on variation in definitions and criteria for SSEPs, can be found on the online CoSTR and are supported by the SysRev.[125,168] Five studies on SSEPs were identified.[133,150,169–171] The overall certainty

of the evidence was rated as very low. Because of the inconsistency in N20 amplitude thresholds and timing of assessment, no meta-analyses were performed. Results of included studies are summarized in Table 14.

Prior Treatment Recommendations

None (new recommendation)

2023 Treatment Recommendation

We suggest against using the amplitude of the N20 SSEP wave to predict good neurological outcome of adults who are comatose after cardiac arrest (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence to decision table is provided in Appendix A.[168] Key points include the following:

- Although very low–certainty evidence suggests that a high N20 amplitude predicts good neurological outcome after cardiac arrest with high specificity, the amplitude threshold for this prediction varied widely across studies.
- The methods to calculate the N20 amplitude were inconsistent.
- Observational evidence shows that sedative drugs, especially midazolam, decrease the N20 amplitude.
- The optimal timing for predicting good outcome by using SSEP amplitude has yet to be established.
- Lack of blinding introduces bias.
- Any possible withdrawal of life-sustaining therapies in post–cardiac arrest patients should be undertaken only by using several prognostication modalities according to the 2020 CoSTR on the prediction of poor outcome, which includes distinct recommendations.[123,124]

Task Force Knowledge Gaps

- The methods to calculate the N20 SSEP amplitude need to be standardized.
- The optimal N20 SSEP amplitude for predicting good outcome needs to be established.
- The interrater variability in the assessment of the N20 SSEP amplitude must be investigated.
- The effects of sedation on the N20 SSEP amplitude must be investigated.
- There is still limited evidence on the correlation between time after ROSC and the N20 SSEP amplitude.

ALS Topics Reviewed by EvUps

Topics reviewed by EvUps are summarized in Table 15, with the PICOST, existing treatment recommendation, number of studies identified, key findings, and whether

Table 14. Amplitude of the N20 Wave of the Short-Latency SSEPs to Predict Favorable Neurological Outcome at 6 Months or ICU Discharge

Author, y	Sample size, n	Threshold value, μV	Timing, h	Timing outcome	Sensitivity (95% CI), %	Specificity (95% CI), %
Scarpino et al,[150] 2021	218	>3	12	6 mo	61.2 (50.0–71.6)	88.7 (82.1–93.5)
Scarpino et al,[150] 2021	218	>4		6 mo	48.2 (37.3–59.3)	91.0 (84.8–95.3)
Scarpino et al,[150] 2021	218	>5.3		6 mo	25.9 (17.0–36.5)	99.2 (95.9–100.0)
Scarpino et al,[150] 2021	218	>10		6 mo	5.9 (1.9–13.2)	100.0 (97.8–100.0)
Scarpino et al,[150] 2021	260	>4	24	6 mo	49.4 (38.7–60.2)	89.5 (83.9–93.6)
Scarpino et al,[150] 2021	260	>5		6 mo	37.1 (27.1–48.0)	93.0 (88.1–96.3)
Scarpino et al,[150] 2021	260	>8		6 mo	15.7 (8.9–25.0)	97.1 (93.3–99.0)
Oh et al,[133] 2019	192	>2.31	48–72	6 mo	52.9 (38.5–67.1)	96.5 (91.9–98.8)
Glimmerveen et al,[171] 2020	129	>3.6		6 mo	32.3 (16.7–51.4)	95.9 (89.9–98.9)
Oh et al,[133] 2019	192	>5.04		6 mo	9.8 (3.3–21.4)	100.0 (97.9–100.0)
Benghanem et al,[170] 2022	82	>3.2	72	3 mo	29.0 (23.0–34.0)	93.0 (90.0–96.0)
Benghanem et al,[170] 2022	82	>4		3 mo	14.0 (10.0–18.0)	95.0 (92.0–97.0)
Scarpino et al,[150] 2021	240	>4		6 mo	50.6 (39.0–62.2)	85.9 (79.6–90.8)
Scarpino et al,[150] 2021	240	>6.2		6 mo	24.7 (15.6–35.8)	92.6 (87.5–96.1)
Scarpino et al,[150] 2021	240	>9		6 mo	14.3 (7.4–24.1)	97.5 (93.8–99.3)
Endisch et al,[169] 2015	293	>4.197	24–96	ICU discharge	27.5 (20.3–35.6)	92.1 (86.5–95.8)
Endisch et al,[169] 2015	293	>7.194		ICU discharge	9.2 (5.0–15.1)	97.4 (93.4–99.3)

ICU indicates intensive care unit; and SSEP, somatosensory evoked potential.

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Table 15. ALS Topics Reviewed With EvUps

Topic/ PICOST	Year last updated	Existing treatment recommendation	RCTs since last review	Observational studies since last review	Key findings	Sufficient data to warrant SysRev?
Cardiac arrest in pregnancy	2020	We suggest delivery of the fetus by perimortem cesarean delivery for women in cardiac arrest in the second half of pregnancy (weak recommendation, very low–quality evidence). There is insufficient evidence to define a specific time interval by which delivery should begin. High-quality usual resuscitation care and therapeutic interventions that target the most likely cause(s) of cardiac arrest remain important in this population. There is insufficient evidence to make a recommendation about the use of left-lateral tilt or uterine displacement during CPR in the pregnant patient.	0	2, plus 1 SysRev of extracorporeal life support in pregnancy (mostly case reports and series) and 1 SysRev of maternal positioning during CPR	Case series of 7 patients with cardiac arrest and perimortem cesarean delivery. No women survived and 3 neonates survived.	No
Steroids after ROSC from cardiac arrest	2010 (intra-arrest steroids reviewed in 2015, EvUps in 2019 and 2021)	There is insufficient evidence to support or refute the use of corticosteroids alone or in combination with other drugs during cardiac arrest.	1	None	RCT of adults with IHCA, randomized to methylprednisolone or placebo. No difference in any outcomes. Limited by very few patients surviving with good neurological outcome in either group, baseline imbalance between groups, and cross-contamination/steroids use in placebo group.	No

ALS indicates advanced life support; CPR, cardiopulmonary resuscitation; EvUp, evidence update; IHCA, in-hospital cardiac arrest; PICOST, population, intervention, comparator, outcome, study design, time frame; RCT, randomized controlled trial; ROSC, return of spontaneous circulation; and SysRev, systematic review.

a SysRev was deemed worthwhile provided. Complete EvUps can be found in Appendix B.

PEDIATRIC LIFE SUPPORT

ECPR for Cardiac Arrest in Pediatrics (SysRev)

Rationale for Review

The continuous evidence evaluation process to produce the CoSTR for this topic for children and for adults started with a SysRev in 2018.[105] Considering the new evidence available on this topic both in children and in adults, the writing panel decided to update the SysRev (PROSPERO CRD42022341077).[106] Evidence was sought and considered by the ALS Task Force and the PLS Task Force groups. The CoSTR for adults is published separately by the ALS Task Force, and the evidence in children is included here. The full online CoSTR can be found on the ILCOR website.[174]

PICOST

- Population: Children (<18 years of age) with cardiac arrest in any setting (out of hospital or in hospital).
- Intervention: ECPR including ECMO or cardiopulmonary bypass during cardiac arrest
- Comparator: Manual or mechanical CPR
- Outcome: Any clinical outcome
- Study design: This was an update of the ILCOR SysRev addressing ECPR for cardiac arrest in 2018. New RCTs, non-RCTs, and observational studies (cohort studies and case-control studies) with a control group (patients not receiving ECPR) were included. Ecological studies, case series, case reports, reviews, abstracts, editorials, comments, letters to the editor, and unpublished studies were not included. Studies assessing cost-effectiveness were included for a descriptive overview. Studies exclusively assessing the use of extracorporeal life support for cardiac or respiratory failure after sustained ROSC were not included. Studies assessing extracorporeal circulation for deep hypothermia (or other conditions) were included only if cardiac arrest was documented.
- Time frame: The search included the dates January 1, 2018, to June 21, 2022. All languages were included if there was an English abstract or an English full-text article.

Consensus on Science

The updated SysRev[106] identified 4 observational studies in children. All studies that included children evaluated IHCA events. There were no published or registered randomized clinical trials comparing ECPR with no ECPR in children. The calendar years of the events included in studies ranged from 2000 to 2017. The number of children included ranged from 17 to 20 654, and the number receiving ECPR ranged from 6 to 1670.

Two studies were secondary analyses of the THAPCA IHCA trial (Therapeutic Hypothermia After Pediatric Cardiac Arrest) in which patients >2 days to <18 years of

age who were comatose after IHCA were randomized to 1 of 2 targeted temperature regimens.[175] In 1 secondary analysis,[176] odds of survival were lower in the patients supported with ECMO (n=180) at the time of initiation of targeted temperature therapy compared with the no ECMO group (n=149; OR for survival at 12 months, 0.52 [95% CI, 0.29–0.94]; OR for survival at 12 months with Vineland Adaptive Behavior Scales Second Edition [VABS-II] score ≥70, 0.34 [95% CI, 0.17–0.67]).

Another secondary analysis of the THAPCA IHCA trial compared the cognitive and neurological scores in 12-month survivors with prearrest VABS-II score ≥70 between 3 groups: those treated with ECPR (n=57), those who did not receive ECMO (n=56), and those treated with ECMO later in their course (n=14).[177] VABS-II composite scores at 12 months were normal (≥70) for 39 ECPR survivors (70.9%), 47 survivors treated with no ECMO (83.9%), and 10 survivors who received later ECMO (71.4%; OR for survival with VABS-II score ≥70, 0.49 [95% CI, 0.22–1.12] in ECPR survivors compared with the other 2 groups combined). The Pediatric Resuscitation After Cardiac Arrest form was used to score conventional age-appropriate neurological examinations.[178] Neurological examination scores in the none/minimal impairment to mild impairment range were observed for 28 ECPR survivors (59.5%), 33 survivors treated without ECMO (73.3%), and in 10 survivors treated with later ECMO (83.3%). Cognitive assessments were completed with the VABS-II, the Mullen scale,[179] and the Weschler Abbreviated Scale of Intelligence assessment.[180] Cognitive and neurological score distributions were similar between ECPR survivors and the no-ECMO and later-ECMO groups.

A third study used an administrative inpatient national database in the United States to evaluate children with *International Classification of Diseases, 10th Revision* codes for cardiac arrest and ECMO on the same day and thus assumed to have received ECPR.[181] These were compared with those with codes for a cardiac arrest only. There was no difference in mortality between patients with ECPR (cardiac arrest and same-day ECMO) and those with CPR without ECMO (59.7% versus 60.2%, OR, 0.98 [95% CI, 0.88–1.08]; $P<0.681$). Secondary outcomes suggest that the group with ECPR (cardiac arrest and same-day ECMO) had longer lengths of stay and higher hospitalization costs compared with those with cardiac arrest and no ECMO.

A fourth study at a single center evaluated the quality of resuscitation measures with video recordings in 6 ECPR and 11 no-ECPR cardiac arrest events.[182] The OR for survival to hospital discharge was reported as 0.53 (95% CI, 0.04–6.66) for the ECPR group compared with those with no ECPR. Similarly, the odds of having a Functional Status Scale[183] score of 1 at hospital discharge were calculated to be 0.53 (95% CI, 0.04–6.66) for the ECPR groups compared with those with no ECPR. ECPR events were associated with lower adherence to resuscitation guidelines compared with CPR-only events.

Collectively, these 4 pediatric studies favored no ECPR, but the CIs, when available, were broad, and risk of bias was assessed as critical for all studies.

Treatment Recommendations (Unchanged From 2021)

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

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[174] Key discussion points included the following:

- In making this weak recommendation, the PLS Task Force noted that in select pediatric patient populations (ie, cardiac arrest with cardiac disease), the practice of using ECPR has become widespread across some institutions with systems that support postoperative cardiac surgical ecosystems.
- The task force acknowledges that ECPR is a complex system intervention that requires considerable resources and sustained training that may not be universally available.

Task Force Knowledge Gaps

- There are no comparative prospective studies or randomized trials of ECPR in children.
- Whether ECPR is beneficial in selected IHCA populations (eg, noncardiac) or in OHCA populations
- How the transition from conventional CPR to ECPR affects the quality of resuscitation measures
- How best to provide closed-chest CPR and transition to a peripheral or central ECPR cannulation (with or without a sternotomy) or how to best perform open-chest CPR in the context of surgical instrumentation for central ECPR
- How best to provide immediate and early post–cardiac arrest care with ECPR (temperature control, oxygenation, decarboxylation, perfusion pressure, transfusion therapies)
- Reporting of studies using ECPR is heterogeneous and not standardized; this domain of resuscitation research would benefit from applying core definitions from the Utstein reporting standards and incorporating the pediatric COSCA.[184] Moreover, an update in Utstein reporting definitions would serve to enhance the reporting of resuscitation measures applied during this technique.

Prediction of Survival With Good Neurological Outcome After ROC Following Pediatric Cardiac Arrest: Combined Prognostic SysRev

Rationale for Review

The PLS Task Force undertook a SysRev considering the use of individual prognostic tests using clinical signs, blood biomarkers, brain electrophysiology, and brain imaging to help the clinician in predicting a good neurological outcome (PROSPERO registration CRD42021279221). For all topics, the search included studies from database inception to December 31, 2022.

This assessment is different from predicting a poor neurological outcome, which may involve consideration of withdrawal of life-sustaining therapies. Recommendations for or against tests to predict good neurological outcomes cannot automatically be transferred to recommendations for poor outcome prediction, and further research is required for this purpose.

The PLS Task Force defined good neurological outcome prediction as imprecise when the FPR was >30%. However, there is no universal consensus on what the acceptable limits for imprecision should be in prediction of good neurological outcome for infants and children after cardiac arrest.

All evaluated tests were used in combination with other tests by clinicians in these studies.

Except when 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. In addition, for all topics, the available evidence had a high risk of bias based on heterogeneity across studies, few studies and 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, Comparator, Outcome, Study Design, and Time Frame for All Neuroprognostication PICOSTs

- Population: Children (<18 years of age) who achieve an ROC, which includes a 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 patients with cardiac arrest could be evaluated separately.
- Intervention: Index prognostic tests, recorded <12 hours, 12 to <24 hours, 24 to <48 hours, 48 to <72 hours, 72 hours to <7 days, 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: Prediction of survival with good neurological outcome defined as a Pediatric CPC score of 1, 2, or 3 or VABS-II score ≥70 at the pediatric ICU (PICU) or hospital discharge, 1 month or later.
- Study design: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Case series were considered if >5 cases were reported. Unpublished studies (eg, conference abstracts, trial protocols) and animal studies were excluded. We selected studies for which the sensitivity and FPR of the prognostic (index) test were reported.
- Time frame: All years and all languages were included if there was an English abstract; unpublished studies (eg, conference abstracts, trial protocols) were excluded. The search was initially run on February 17, 2022, and was updated December 31, 2022.

Clinical Examination for the Prediction of Survival With Good Neurological Outcome

Intervention: Includes every part of a bedside neurological clinical examination, including pupillary response (assessed using manual light reflex or automated pupillometry), level of coma (eg, GCS score or Full Outline of Unresponsiveness score), and brainstem reflexes.

Consensus on Science

See the ILCOR website for the full online CoSTR.[185]

Pupil Reactivity

The predictive ability of presence of pupil reactivity to classify good neurological outcome was evaluated in 8 studies[186–193] in 402 patients within 1, 6 to 12, 24, and 72 hours after resuscitation. Most studies had a sensitivity >82% at all assessment times, and the corresponding FPR ranged from 3.2% to 67%. Within 12 hours of ROC, the FPR was <33% in 3 of 4 studies reporting this time period.[187,188,191] FPR increased to 38% to 68% at 24 to 72 hours, and the corresponding sensitivity for predicting good neurological outcome was 100% at 48 to 72 hours after ROC.[186,190] No studies evaluated automated pupillometer monitoring devices.

Coma Level

The relationship between coma assessment using the GCS motor score alone or total GCS and good neurological

outcome at ICU discharge, hospital discharge, and 6 months was evaluated in 3 studies[191,193,194] including 296 patients. In 1 study, GCS motor score of ≥4 within 1 hour and at 4 to 6 hours after ROC had a sensitivity of 17% and 50% for predicting good neurological outcome at 6 months, with a corresponding FPR of 6% and 7%, respectively.[191] When total GCS measured at resuscitation or within 1 hour was used, a score of ≥5 predicted good neurological outcome with a low sensitivity of 30% and an FPR of 14%.[194] A total GCS score of ≥8 had a slightly higher sensitivity of 31%, with a low FPR of 6%.[193] However, only 1 study was available to assess each test using total GCS or GCS motor score cutoff or at each testing time point.

Motor Response

The presence of a motor response to any stimulus was evaluated in 1 study[186] at <1, 48, and 72 hours after ROC with up to 27 patients. Sensitivity and FPR improved with time. At <1 hour after ROC, the sensitivity was 38% and FPR was 30%; in comparison, at 72 hours, the sensitivity was 100% and the FPR was 23%.

Brainstem Reflex

The presence of brainstem reflexes to predict good neurological outcome at ICU or hospital discharge was evaluated in 2 studies[188,192] including 118 patients. Evoked responses to pain, gag reflex, and cough reflex were assessed at 6 to 12 hours and at 24 hours. Predictive sensitivity of presence of pain response at 6 to 12 hours was 100% with an FPR of 67%.[188] The presence of both a gag and cough reflex at 24 hours predicted a good neurological outcome with a sensitivity of 40% and FPR of 32% to 35%.[192]

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).

There was no previous recommendation for the use of clinical examination.

2023 Treatment Recommendations

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 brainstem tests after ROC for predicting good neurological outcome in children after cardiac arrest.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[185] Key points include the following:

- For pupillary light reflex, limited evidence suggests that the specificity for prediction of good neurological outcome was highest within 12 hours of ROC after cardiac arrest. There was increased sensitivity (up to 100%) for predicting good outcomes at 48 to 72 hours; however, the point estimates had wide CIs. Pupillary light reflex at 48 to 72 hours should be evaluated for use in predicting poor neurological outcome at these times.
- For all clinical examination modalities, inaccuracy of outcome prediction tests may be due to confounding from the effect of sedatives. No studies reported any assessment of the confounding influence of medication or specifically excluded the presence of residual sedation at the time of clinical examination.
- 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, even if the withdrawal of life-sustaining therapy based on clinical examination has not been documented in any of the studies included in our review.
- The studies inconsistently reported the cointervention of temperature control on the clinical assessments.
- Despite the limitations of the assessment of pupil light reactivity and coma assessment, the balance between the costs and benefits favors benefit.

Task Force 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
- The cost and benefits of the use of pupillometry compared with pupillary light reflex assessment
- Economic cost evaluation and cost-effectiveness studies are required.
- Further research is required on multimodal prognostication, timing, definitions of testing, accurate outcome timing, and outcome definition.
- A better understanding of survivorship after pediatric cardiac arrest—informed by wider research and consultation with patients, children, parents,

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guardians and caregivers, health care professionals, and members of the wider society—is needed to inform correct definitions and a framework of good neurological outcome for prediction research.

Blood Biomarkers for the Prediction of Survival With Good Neurological Outcome

Intervention: Serum biomarkers specific to neuronal damage (eg, NSE, S100B, glial fibrillary acidic protein, NfL) or blood markers of inflammation or systemic ischemic reperfusion (eg, procalcitonin, blood pH, or lactate)

Consensus on Science

See the ILCOR website for the full online CoSTR.[195]

Lactate

Lactate was evaluated in 5 studies.[175,196–199] Three studies documented <7% FPR for lactate <2 mmol/L at <1 hour and at 6 to 12 hours,[175,197,199] although the sensitivity in these studies was low (16%–28%). Lactate <2 mmol/L at 24 to 48 hours was sensitive (69%–86%) for good neurological outcome; however, the FPR was high at 61% and 68%. Lactate <5 mmol/L at <1 hour had moderate sensitivity (66%) and FPR (62%) and at 24 hours had high sensitivity (89%) and low FPR (17%), making the latter a useful test for prediction. Lactate clearance over 48 hours to <2 mmol/L had a high sensitivity (100%) and high FPR (77%).

pH

pH was evaluated in 4 studies.[175,196,197,199] pH thresholds were >7.0, >7.3, and <7.5 at resuscitation and within 1, 6 to 12, and 24 hours of ROC. The blood pH measured after resuscitation or <1 hour from ROC had a wide range of sensitivities of 27% to 95% for predicting good neurological outcome. A pH >7.0 was reported in 3 studies and had a 68% to 98% sensitivity to predict survival and 71% to 97% sensitivity for good neurological outcome. FPR for good neurological outcome was >80% for all except for pH threshold >7.0 at <1 hour after ROC (FPR, 45%) and >7.3 at <1 hour after ROC (FPR, 38%).

Neuronal Biomarkers

Only 1 study including 43 children reported NSE, S100B, and myelin basic protein values.[190] Threshold values were calculated and reported to classify either high sensitivity or low FPR for good neurodevelopmental outcome. At 24 hours, an S100B value of 0.128 ng/mL predicted a good neurodevelopmental outcome with a sensitivity of 100%, with a moderately high FPR of 62%. Sensitivity was high (100%) for predicting good outcome with an NSE threshold of 53.1 ng/mL at 24 hours and 76.7 ng/mL at 48 hours (with a corresponding FPR of 81% and 77%, respectively). Myelin basic protein level of 5.83 ng/mL at 24 hours and 5.43 ng/mL at 48 hours also had a high predictive sensitivity of 100% but high FPR of 96% and 88%, respectively.

Lower threshold values of S100B (0.001 ng/mL at 24 hours), NSE (0.48 ng/mL at 48 hour), or myelin basic protein (0.05 ng/mL at 48 hours) had a sensitivity of 6% to 29% with a corresponding very low FPR of <6% for good neurological outcome.

Studies evaluating additional neuronal biomarkers (eg, glial fibrillary acidic protein, ubiquitin carboxyl-terminal hydrolase-L1, NfL, and tau) in children after cardiac arrest with good and poor outcomes were identified,[200–203] but we were unable to calculate the sensitivity and specificity from the raw data available in the published articles.

Prior Treatment Recommendations

No previous recommendations for the use of specific biomarkers

2023 Treatment Recommendations

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 the prediction of good neurological outcome (good practice statement).

We suggest using a normal plasma lactate value (<2 mmol/L) up to 12 hours after 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 after ROC for predicting good neurological outcome.

We suggest against using pH after 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.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[195] Key points include the following:

- Lactate and pH are potential markers of ischemia, poor perfusion, and anaerobic metabolism and are known to be associated with poor outcomes after cardiac arrest. Lactate metabolism is complex, and consideration of confounders and other predictors is critical.
- Included studies were observational studies and RCTs, but they were not designed primarily to test prognosis of blood biomarkers.
- Lactate is measured by blood gas analyzers and is easily accessible. Considering the low (but not

negligible) cost of testing lactate and pH, a problem of inequity is unlikely but possible. Lactate and blood pH are widely available in settings with ICUs, but many settings do not have ICUs.
- Only 1 study[190] has identified threshold values for 2 blood neuronal biomarkers (S100B and NSE) that are associated with good neurological outcome with a high sensitivity. However, the FPR is high, and these tests require specialized laboratory equipment and are not widely available.
- 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. Lack of blinding is a major limitation of biomarker tests, even if the withdrawal of life-sustaining therapy on the basis of test results was not documented in any of the studies included in our review.

Task Force Knowledge Gaps

- The utility of other candidate biomarkers (eg, NfL, glial fibrillary acidic protein, tau, ubiquitin carboxyl-terminal hydrolase-L1) and whether subgroups may exist in which the FPR is much lower
- Cost-effectiveness of biomarker testing
- Further research is required on multimodal prognostication, timing, definitions of testing, accurate outcome timing, and outcome definition.
- A better understanding of survivorship after pediatric cardiac arrest—informed by wider research and consultation with patients, children, parents, guardians and caregivers, health care professionals, and members of the wider society—is needed to inform correct definitions and framework of good neurological outcome for prediction research.

Electrophysiology for the Prediction of Survival With Good Neurological Outcome

Intervention: Surface bioelectrical recordings from the central nervous system such as EEG and evoked potentials (eg, brainstem auditory-evoked potentials, and short-latency SSEPs). We included studies of the interpretation of raw signals or summary measures derived from processed EEG signals such as amplitude-integrated EEG, quantitative EEG, or BIS.

Consensus on Science

The full online CoSTR can be found on the ILCOR website.[204]

Absence of Clinical or Electrographic Seizure

Twelve studies reported the relationship between absence or presence of seizures in children after cardiac arrest and good neurological outcomes at PICU/hospital discharge, 6 months, and 12 months.[175,188,189,191,198,199,205–210] These studies included 1165 children, and 4 of the 12 studies reported using the ACNS criteria.[189,205,208,210]

Absence of seizures up to 24 hours after ROC had a sensitivity of 50% to 100% with an FPR of 63% to 98% for predicting good neurological outcome at various time points.[191,205,208,209] Absence of seizure after 24 hours had a sensitivity of 50% to 100% with an FPR of 42% to 100% for predicting good neurological outcome.[175,188,189,191,198,199,202,208,210]

Absence of Status Epilepticus

Absence of status epilepticus was reported in 3 studies.[205,209,210] Two of these studies used ACNS criteria to define status epilepticus. Good neurological outcome at PICU/hospital discharge was predicted with a high sensitivity of >90%, although the FPR remained high at 81% to 91%.

Absence of Myoclonic Epilepsy

On the basis of 2 studies, absence of myoclonic seizures predicted good neurological outcomes with a sensitivity of 100% but a very high FPR of 79% to 83% at PICU/hospital discharge.[188,208]

Somatosensory Evoked Potentials

SSEPs, evaluating the presence or absence of N20 waves, were reported in only 1 study, with few patients (n=12) reporting good neurological outcome (Pediatric CPC score 1 to 3) at 3 times (24, 48, and 72 hours).[211] Clinicians were blinded to test results, and the SSEP assessor was blinded to outcome. The sensitivity for prediction of good neurological outcome was 100% at 24 and 48 hours and 83% at 72 hours, with a very low FPR of 0% at all time points but wide 95% CIs (0%–71%).

Presence of Continuous or Normal EEG Background

The presence of a normal EEG background (defined as normal, continuous and reactive, continuous and unreactive, and nearly continuous by ACNS definitions) was reported in 10 studies with 18 different testing timings and included 563 patients (although there was a risk of overlapping patient populations).[188–190,192,205,206,208–210,212] Studies using normal or continuous EEG reported a low to moderate sensitivity of <50% at 10 of 18 testing times for predicting good neurological outcome. However, the FPR was also low (<50% in all cases and <30% in 11/18). In the largest study,[209] the sensitivity of continuous EEG at 6 to 12 hours was 7.3% with an FPR of 0%. The FPR was higher in studies assessing prognostic accuracy at and beyond 48 hours after ROC.

Absence of Attenuated, Isoelectric, or Flat EEG Background

The absence of an attenuated, isoelectric, or flat EEG was reported in 10 studies including up to 526 patients (although there was a risk of overlapping patient populations).[188–190,192,205,206,208–210,212] The sensitivity to predict a

good neurological outcome was very high in 8 studies (91%–100%)[188,189,192,202,205,208,209,212]; however, there was a wide range of FPR of 0% to 83%, with the majority of studies reporting >40% FPR.

Absence of Burst Suppression, Burst Attenuation, or Generalized Periodic Epileptiform Discharges on EEG

Absence of burst suppression, burst attenuation, or generalized periodic epileptiform discharges was reported in 6 unblinded studies including 395 patients.[188,192,205,208–210] Sensitivity increased from 81% to 100% within 6 to 12 hours, to a highly sensitive test (100% with high precision [95% CI, 100%–100%]) at 24, 48, and 72 hours. However, the FPR was high at all time periods (67%–100%) for predicting a good neurodevelopmental outcome.

Presence of a Reactive EEG

The presence of reactivity within an EEG was reported in 3 studies, with a moderate sensitivity for good neurological outcome of 53% to 80% between 6 and 72 hours.[192,208–210] The FPR ranged from 7% to 27% up to 24 hours after ROC in 2 studies.[192,208] However, it increased to 50% at 48 hours after ROC in 1 study.

Presence of Sleep II Architecture or Sleep Spindles on EEG

The presence of sleep II architecture or sleep spindles was reported in 2 studies including 123 patients at 6 to 12 hours and 24 hours following ROC after cardiac arrest. The presence of these features had a predicted sensitivity of 57% to 80% and low FPR (8.3%–16%).[189,192]

Presence of EEG Variability and EEG Voltage Variability

EEG variability, defined with ACNS criteria, had a moderate sensitivity for predicting good outcome (60%–80%) in 2 studies of 132 patients, with a corresponding FPR of 18% to 50%.[192,208] However, EEG voltage variability had a higher sensitivity (75%–100%) in 1 study at all measured time points (6–12, 24, and 48 hours after ROC) and a higher corresponding FPR of 36% to 67%.[208]

Quantitative EEG Scoring

Only 1 study reported a composite score assessing EEG background from a 24-hour monitoring period, obtained from quantitative EEG using the amplitude integrated EEG trace in 30 patients.[213] A score of >15 had a predicted sensitivity of 94% and FPR of 67% for a good neurological outcome.

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).

2023 Treatment Recommendations

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 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, continuous or normal background EEG between 1 and 72 hours, or EEG reactivity between 6 and 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, EEG voltage, or quantitative EEG score for predicting good neurological outcomes.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[204] Key points include the following:

- ACNS definitions for seizures and EEG indices were followed in only some studies. EEG and SSEP prognostic criteria require clear and reproducible definitions and require validation in the PICU environment.
- 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 require expert neurophysiology input. Studies reported limited information on the handling of this area, and further refinement of definitions and application of recommendation is required.
- There was limited or no accounting for when tests were undertaken in relation to concurrent pharmacological exposure, sedation, and ongoing treatment (eg, targeted temperature management) in patients after cardiac arrest.
- SSEPs have a high level of precision in adult studies of neuroprognostication in comatose patients after cardiac arrest. The PLS Task Force recognizes the lack of available data in children and strongly encourages further multicenter evaluation.

Task Force Knowledge Gaps

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

Brain Imaging for the Prediction of Survival With Good Neurological Outcome

Intervention: Neuroimaging modalities included head CT, brain MRI, cranial ultrasound, or transcranial Doppler ultrasound.

Consensus on Science

See the ILCOR website for the full online CoSTR.[214]

CT Imaging

Head CT to predict good neurological outcome (Pediatric CPC 1–3) was evaluated in 3 studies including 173 patients.[190,210,215] The majority of CT imaging was acquired at 24 or 48 hours after the cardiac arrest. Neurological outcome was assessed on discharge from the ICU or hospital in 2 studies and at 6 months in 1 study. Reported factors from CT included presence and absence of intracranial hemorrhage, cerebral edema or ischemia measured by the reversal sign, gray-white matter differentiation, and sulcal or basal cistern effacement. Two studies described methods of estimating gray-white matter differentiation,[215,216] and 2 studies reported radiologists' qualitative reports.[190,215]

The presence of gray-white matter differentiation on CT at 24 hours had a sensitivity of 64% to 100% and an FPR of 35% to 70%. Absence of CT lesions, edema, or intracranial hemorrhage predicted good neurological outcome with a sensitivity ranging from 72% to 100%; however, a wide range of FPR (14%–90%) was reported. Absence of effacement of sulci or basal cisterns predicted good neurological outcome with a high sensitivity (93%–100%) and an FPR 32% to 73%. Clinicians were not blinded to the CT results in any study.

Magnetic Resonance Imaging

MRI to predict good neurological outcomes was reported in 4 studies including 215 patients.[206,217–219] Median time from ROC to MRI ranged from 3 to 6 days across all studies, although inclusion of patients' MRIs up to 14 days was reported in 3 studies.[206,217,219] Two studies reported the presence or absence of abnormalities in multiple regions of the brain in 3 sequences (diffusion-weighted imaging, T1, and T2).[217,218] Another study presented a composite of presence or absence of 1 (or more) region of abnormality.[206] One study evaluated thresholds of apparent diffusion coefficient and overall qualitative MRI reporting of evidence of hypoxic ischemic injury.[219] Three studies ensured that the neuroradiologist's MRI assessment was blinded to patient clinical status. However, the MRI findings were known by the treating clinicians, and neurological outcome assessment was not blinded.[206,217,218]

Absence of any region of abnormality on restricted diffusion at a median of 4 days after ROC predicted good neurological outcome with a sensitivity of 88% and corresponding very low FPR of 2% in 1 study.[206] Apparent diffusion coefficient threshold $>600\times10^{-6}$ mm^2/s in >93% and $>650\times10^{-6}$ mm^2/s in >89% of brain volume at a median of 4 days after ROC predicted good neurological outcome with a sensitivity of 100% and a low FPR (20%).[219] In the same study, a normal MRI by qualitative reporting of absence of hypoxic ischemic injury predicted a good neurological outcome at 6 months with a sensitivity of 81% and an FPR of 10%.[219]

For individual regions of the brain, at 4 to 6 days after ROC, diffusion-weighted imaging MRI sequence had a sensitivity for predicting good neurological outcome ranging from 67% to 100%, although associated FPR rates were moderate to high. Absence of lesions in the lentiform regions on T2-weighted imaging had a sensitivity of 67% and the lowest FPR (7.7%) for any single region of the brain.

Transcranial Doppler Ultrasound

The prediction of good neurological outcome using presence of flow velocities of intracranial vessels measured on transcranial Doppler was evaluated in 1 study including 17 patients who were treated with hypothermic targeted temperature management.[220] Flow patterns without any reversal (or absence of diastolic) flow, mean flow velocity, and pulsatility index were assessed before, during, and after hypothermia therapy. Continuous-flow velocities without reversal of diastolic flow pattern had a sensitivity of 100% and an FPR of 44%. Within 1 hour of the event in the prehypothermia phase, mean flow velocity had a sensitivity for good neurological outcome of 38% and an FPR of 0%, and having a normal pulsatility index had a sensitivity of 38% and an FPR of 22%. In the hypothermia phase, mean flow velocity had a sensitivity of 25% and an FPR of 11%; pulsatility index had a higher sensitivity of 100% and an FPR of 22%. By 72

hours, normal pulsatility index predicted a good outcome, with 88% sensitivity and 11% FPR. Clinicians were not blinded to the transcranial Doppler results in this study.

Cranial Ultrasound

We identified no studies examining the role of cranial ultrasound and good neurological outcome after cardiac arrest in children.

Prior Treatment Recommendations

No previous recommendations for the use of brain imaging

2023 Treatment Recommendations

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 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.

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[214] Key points include the following:

- The low FPR (high specificity) for normal MRI on global assessment for predicting good neurological outcome reduces the chance of false optimism if a normal MRI predicts a good neurological outcome.
- The sensitivity of a normal MRI or CT to predict a good neurological outcome is moderate to high, but up to 30% may be falsely categorized, and a falsely pessimistic prediction may be made. Therefore, with the very low–certainty evidence, we cannot make a recommendation for or against the use of normal or abnormal MRI or CT for predicting poor neurological outcomes.
- The precision of MRI and CT is affected by the timing of the acquisition of the image; images may be unrevealing if obtained outside the window of peak cellular edema and ischemia.
- The definition of presence or absence of injury on diffusion-weighted imaging or threshold values for apparent diffusion coefficient on MRI or GWR on CT was inconsistent in the included studies.
- Both MRI and CT are 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

- Neuroimaging for prognostication after cardiac arrest appears promising, but more research is required in infants and children.
- A standardization of definitions and assessment of optimal thresholds for GWR calculation on CT and diffusion-weighted imaging and apparent diffusion coefficient thresholds on MRI is needed.
- The optimal timing for prognostication with CT and MRI after cardiac arrest needs to be determined; studies assessing serial imaging after cardiac arrest are desirable.
- The role of assessing regional areas of the brain for predicting outcome or the use of magnetic resonance spectroscopy
- Cost-effectiveness of CT and MRI for prognostication
- Further work is needed on multimodal prognostication, timing, definitions of testing, and accurate outcome timing and definition.
- A better understanding of survivorship after pediatric cardiac arrest—informed by wider research and consultation with patients, children, parents, guardians and caregivers, health care professionals, and members of the wider society—is needed to inform correct definitions and framework of good neurological outcome for prediction research

PLS Topics Reviewed by EvUps

Topics reviewed by EvUps are summarized in Table 16, with the PICO, existing treatment recommendation, number of studies identified, key findings, and whether a SysRev was deemed worthwhile provided. Complete EvUps can be found in Appendix B.

NEONATAL LIFE SUPPORT

Maintaining Normal Temperature: Preterm (SysRev)

Rationale for Review

A previous SysRev conducted for ILCOR concluded that there was a dose-responsive association between hypothermia on admission to a neonatal unit or postnatal ward and increased risk of mortality and other adverse outcomes.[221] These findings are supported by more recent large observational studies.[222,223] A SysRev estimated that hypothermia was common among infants born in both hospitals and homes, even in tropical environments.[224] A SysRev was initiated from a priority list from the ILCOR Neonatal Life Support (NLS) Task Force (PROSPERO

Table 16. PLS Topics Reviewed by EvUps

Topic/PICOST	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Pulse check accuracy	2020	The ILCOR treatment recommendations from 2020 remain unchanged: Palpation of a pulse (or its absence) is not reliable as the sole determinant of cardiac arrest and need for chest compressions. If the individual is unresponsive or not breathing normally and there are no signs of life, lay rescuers should begin CPR. In infants and children with no signs of life, health care providers should begin CPR unless they can definitely palpate a pulse within 10 s.	0	0	In the 2020 EvUp on the accuracy of pulse check in detecting ROC after cardiac arrest in children, 2 studies were identified describing the use of manual pulse check in pediatric cardiac arrest. Our EvUp in 2022 identified several adult studies assessing the utility of manual pulse palpation at different sites and manual pulse palpation vs other innovative techniques such as arterial Doppler ultrasound, POCUS, photoplethysmography, and ECG-based pulse detection. However, no new pediatric studies were identified. Despite several recent adult studies comparing manual pulse palpation with other methods of detecting ROC after arrest, there remains very little pediatric-specific evidence in this area.	No
Pad size, type, and placement for pediatric defibrillation	2020	The ILCOR treatment recommendations remain unchanged: 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. Either self-adhesive defibrillation pads or paddles may be used in infants and children in cardiac arrest.	0	0	In the 2020 EvUp on the use of various pad sizes, types, and placement for pediatric defibrillation, 1 new pediatric study was identified since 2010 examining the use of different defibrillator pad positions in children with shockable rhythms in cardiac arrest. Our EvUp in 2022 did not find any new pediatric studies on the topics of defibrillator pad size, type, or placement in pediatric cardiac arrest. There are few pediatric-specific studies on the topics of defibrillator pad size, type, or placement in pediatric cardiac arrest.	No
Antiarrhythmics for children in cardiac arrest with shockable rhythms at any time during CPR or immediately after ROSC	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).	0	1	The only new evidence since the last SysRev in 2018 is an observational study using the GWTG database that found no significant difference in outcomes when propensity-matched scores were used to compare children who received lidocaine and children who received amiodarone for shockable rhythm during cardiac arrest. A SysRev was also reported in a brief research letter with limited description of methods.	No
Adenosine use in SVT	2020	This treatment recommendation is unchanged from 2010.	0	0	There have not been any new studies on the use of adenosine in SVT since our last review. For infants and children with SVT with a palpable pulse, adenosine should be considered the preferred medication. Verapamil may be considered an alternative therapy in older children, but it should not be routinely used in infants. Procainamide or amiodarone given by a slow intravenous infusion with careful hemodynamic monitoring may be considered for refractory SVT. Moderate-quality evidence shows no differences in effects of adenosine and calcium channel antagonists for treatment of SVT on reverting to sinus rhythm, and low-quality evidence suggests no appreciable differences in the incidence of hypotension. A study comparing patient experiences and prospectively studied adverse events would provide evidence on which treatment is preferable for management of SVT.	No

(*Continued*)

Table 16. Continued

Topic/PICOST	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Energy doses for pediatric defibrillation	2015	The ILCOR treatment recommendations from 2020 remain unchanged: We suggest the routine use of an initial dose of 2–4 J/kg of monophasic or biphasic defibrillation waveforms for infants or children in VF or pVT cardiac arrest. There is insufficient evidence on which to base a recommendation for second and subsequent defibrillation dosages.	0	1	The 2020 ScopRev identified a single 2019 SysRev that identified no pediatric studies linking the initial or cumulative energy delivered with survival to hospital discharge and no link between long-term survival or survival with good neurological outcome. Meta-analysis could not be performed because the component population groups were extremely heterogeneous. Our EvUp in 2022 identified 1 new pediatric study on this subject. This in-hospital registry study had been noted in the 2020 ScopRev but had not been published until after the initial search and thus was not included in the analysis. Differences remain in the first shock dose recommended by ILCOR member councils, with the ERC and ANZCOR recommending 4 J/kg for the first and all subsequent shocks and the AHA recommending an initial dose of 2–4 J/kg (for ease of teaching, a dose of 2 J/kg is used in algorithms and training materials). For refractory VF, the AHA guidelines recommend increasing the 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 recently performed SysRev failed to show a significant benefit of one dosing regimen over another but was hampered by small sample sizes and study heterogeneity. The more recent large pediatric in-hospital registry study provided support for a 2–J/kg dose for initial defibrillation but did not provide guidance for subsequent doses.	No
Single or stacked shocks for pediatric defibrillation (PLS 389)	2020	The ILCOR treatment recommendations from 2020 should remain unchanged: 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.	0	0	In the 2020 EvUp, there were no new pediatric studies since 2010 on the comparative clinical outcomes from the use of single defibrillation vs >1 shock for the initial or subsequent defibrillation attempt(s) in children with shockable rhythms in cardiac arrest in any setting. They identified a single observational study on transthoracic impedance during defibrillation in children ≥8 y of age (n=5) that suggested that stacked shocks may not improve defibrillation success. Our EvUp in 2022 did not find any new pediatric studies on this subject. As in the previous EvUp, we identified several adult studies, but they were excluded in view of the differences in physiology and pathophysiology of shockable rhythms in pediatric cardiac arrests and may not be extrapolatable to the pediatric population. Despite several recent adult studies comparing single and stacked shocked in very selected settings, there remains very little pediatric-specific evidence in this area.	No

(*Continued*)

Table 16. Continued

Topic/PICOST	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Epinephrine frequency during CPR	2020	We suggest that the initial dose of epinephrine in pediatric patients with both nonshockable IHCA and OHCA should 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 for the optimal epinephrine interval for subsequent epinephrine doses in pediatric patients with IHCA or OHCA.	0	5	Time to first dose of epinephrine–OHCA: New evidence suggests that epinephrine may not be effective if given >15 minutes after EMS arrival. The evidence is low quality from observational studies. Time to first dose of epinephrine–IHCA: One study examined hospital-level average timing of first dose of epinephrine and found extensive differences between institutions. After adjustment for patient and hospital variables, those higher-performing hospitals (ie, shorter time to first dose of epinephrine) had higher ROSC and 24-h survival but no difference in critical outcomes. For the population with poorly perfused bradycardia requiring CPR but with a pulse, epinephrine administration was associated with worse critical outcomes and increased progression to pulselessness. This is a different population from those with cardiac arrest but was included in this EvUp because the patients received CPR for >2 min. The treatment for bradycardia is reviewed in a different PICOST and should not be considered in the context of this PICOST. Epinephrine dosing interval: One study examined the dosing interval of epinephrine during IHCA and found that an interval of ≤2 min compared with >2 min had improved critical outcomes.	No
Bedside ultrasound to identify perfusing rhythm	2020 (ScopRev)	There is insufficient evidence to recommend for or against the routine use of echocardiography during a pediatric arrest.	0	1	This topic was covered in guidelines from the AHA and the ERC. We identified 1 small case series. Echocardiography may be considered to identify potentially treatable causes of an arrest when appropriately skilled personnel are available, but the benefits must be carefully weighed against the known deleterious consequences of interrupting chest compressions.	No
End-tidal CO_2 monitoring during CPR	2020 (ScopRev)	The confidence in effect estimates is so low that the panel decided a recommendation was too speculative.	1	5	This topic was covered in guidelines from the AHA and the ERC. We identified 1 randomized clinical trial, 4 observational studies, and 1 SysRev of pediatric extracorporeal resuscitation that reported end-tidal CO_2 monitoring during CPR or outcomes. The available data indicate that monitoring of end-tidal CO_2 contributes to improving the quality of CPR and to the adherence to current guidelines. However, the impact of end-tidal CO_2 monitoring and feedback on patient outcomes has not been demonstrated, and that is the main focus of our PICOST.	No

(*Continued*)

Table 16. Continued

Topic/PICOST	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Invasive blood pressure monitoring during CPR	2020 (ScopRev)	The confidence in effect estimates is so low that the panel decided a recommendation was too speculative.	1	2	This topic was covered in guidelines from the AHA and the ERC. We identified 1 RCT and 2 observational studies using patients from the RCT population. The potential value of personalized hemodynamic-directed CPR, when CPR efforts are adjusted in view of predefined (diastolic) blood pressure goals and not limited by current standard guidelines, has yet to be defined. Indeed, current evidence suggests that at present there is a low rate of use of diastolic blood pressure during resuscitation.	No
Use of NIRS during cardiac arrest	2020 (ScopRev)	There has not been, to date, a recommendation for the use of NIRS in cardiopulmonary arrest to guide resuscitation efforts or predict outcome.	0	2	Our EvUp in 2022 identified 1 observational study that reported NIRS monitoring during CPR or outcomes and 1 abstract. The observational study evaluated 21 patients with 23 events and found an association between higher rSo_2 measurements during the entire monitored event and last 5 min of the event with ROSC. The abstract of 32 patients including children with congenital heart disease from 3 centers did not show an association with outcomes or on multivariable analysis. There remains very little pediatric-specific evidence examining the use of NIRS during cardiac arrest. Our EvUp only identified 1 small observational study and 1 abstract. Therefore, a SysRev of pediatric patients with cardiac arrest is not justified at this time. There continue to be insufficient data to support or advise against a treatment recommendation related to NIRS use during CPR to provide physiological feedback to guide resuscitation efforts or predict outcome.	No
Resuscitation of the pediatric patient with a single-ventricle, post–stage I repair	2020 (EvUp)	The PLS task force recommendations from 2020 for the pediatric population remain unchanged. Standard resuscitation (prearrest and arrest) procedures should be followed for infants and children with single-ventricle anatomy after stage I repair. Neonates with a single ventricle before stage I repair who demonstrate shock caused by elevated pulmonary to systemic flow ratio might benefit from the induction of mild hypercarbia ($Paco_2$ 50–60 mm Hg); this can be achieved during mechanical ventilation by reducing minute ventilation, adding CO_2 to inspired air, or administering opioids with or without chemical paralysis.	0	4	No new RCTs were identified. Four additional publications fulfilled inclusion criteria; however, none would change the current treatment recommendations of standard resuscitation procedures for infants and children with single-ventricle anatomy after stage I repair. There is some evidence for the use of ECMO in postcardiotomy patients with single-ventricle anatomy and ECPR use in patients with single-ventricle anatomy, but that topic should be included in the SysRev on ECPR by the ALS with PLS input.	No

(*Continued*)

Table 16. Continued

Topic/PICOST	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Resuscitation of the pediatric patient with single-ventricle, status–post–stage III/Fontan/total cavopulmonary connection/anastomosis in cardiac arrest	2010	This treatment recommendation is unchanged from 2010 with the exception of limiting the recommendation to children with hemi-Fontan or BDG physiology who are in a prearrest state; hypercarbia achieved by hypoventilation may be beneficial to increase oxygenation and cardiac output. Negative-pressure ventilation, if available, may be beneficial for children with either hemi-Fontan or BDG or Fontan physiology by increasing cardiac output. During cardiopulmonary arrest, it is reasonable to consider ECPR for patients with Fontan physiology. There is insufficient evidence to support or refute the use of ECPR in patients with hemi-Fontan or BDG physiology.	0	1	This EvUp was performed to identify any evidence about this topic published after the PLS Task Force's most recent review in 2010. The EvUp identified 1 registry-based study that reported outcomes of infants and children with Fontan or BDG who had circulatory support initiated during a periarrest phase. The PLS Task Force agreed that there is insufficient evidence to recommend a new SysRev, and the 2010 treatment recommendation remains in effect, with the addition of a brief explanatory phrase within brackets. Optimizing outcomes for patients with single-ventricle physiology status–post–total cavopulmonary connection (Fontan palliation) requires a nuanced understanding of anatomic and physiological considerations, as well as cardiopulmonary and cardiocerebral interactions. The previous EvUp was performed by the PLS Task Force in July 2018 after revision of the original search strategy to include patients with single-ventricle anatomy who may undergo surgical palliation with PAB or nonsurgical repair in the cardiac catheterization laboratory to include PDA stent (hybrid palliation). This EvUp has identified no new RCTs or sufficient new data to proceed to full SysRev.	No
Resuscitation of the pediatric patient with hemi-Fontan/BDG circulation in cardiac arrest	2010		0	1	This EvUp was performed to identify any evidence about this topic published after the PLS Task Force's most recent review in 2010. The EvUp identified 1 registry-based study that reported outcomes of infants and children with Fontan or BDG who had circulatory support initiated during a periarrest phase.	No
Resuscitation of children with cardiac arrest associated with sepsis	New	There is no treatment recommendation at this time.	0	0	The management of children with septic shock–associated cardiac arrest has not been previously reviewed by the PLS Task Force. PICOST: Population: Infants and children in cardiac arrest with sepsis Intervention: Specific alteration in treatment algorithm Comparator: Standard care (according to current treatment algorithm) Outcome: All Study design: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Time frame: All years and all languages were included as long as there was an English abstract. This EvUp was requested to determine the available evidence about this topic. The EvUp identified several studies involving prevention of cardiac arrest, but there was insufficient evidence of unique management approaches to the children with septic shock–associated cardiac arrest.	No

(*Continued*)

Table 16. Continued

Topic/PICOST	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Fio_2 titrated to oxygenation during pediatric cardiac arrest	2020	This treatment recommendation is unchanged from 2010. There is insufficient information to recommend a specific inspired oxygen concentration for ventilation during attempted resuscitation after cardiac arrest in infants and children.	0	0	This PICOST remains a challenge because finding any data during nonneonatal cardiac arrest is problematic. Although there is great interest in titration of oxygen after cardiac arrest and, more specifically, in the prevention of post-ROSC hyperoxia, titration of oxygen for intra-arrest management remains unreported in the human literature.	No

AHA indicates American Heart Association; ALS, advanced life support; ANZCOR, Australian and New Zealand Committee on Resuscitation; BDG, bidirectional Glenn; CPR, cardiopulmonary resuscitation; ECMO extracorporeal membrane oxygenation; ECPR, extracorporeal cardiopulmonary resuscitation; EMS, emergency medical services; ERC, European Resuscitation Council; EvUp, evidence update; GWTG, Get With The Guidelines; IHCA, in-hospital cardiac arrest; ILCOR, International Liaison Committee on Resuscitation; NIRS, near-infrared spectroscopy; OHCA, out-of-hospital cardiac arrest; PICOST, population, intervention, comparator, outcome, study design, time frame; PAB, pulmonary artery banding; $Paco_2$ partial pressure of oxygen, arterial; PDA, patent ductus arteriosus; PLS, pediatric life support; POCUS, point-of-care ultrasound; pVT, pulseless ventricular tachycardia; RCT, randomized controlled trial; ROC, return of circulation; ROSC, return of spontaneous circulation; rSo_2 regional cerebral oxygen saturation; ScopRev, scoping review; SysRev, systematic review; SVT, supraventricular tachycardia; and VF, ventricular fibrillation.

registration CRD42021267301). The full online CoSTR can be found on the ILCOR website.[225]

PICOST

- Population: Preterm infants (<34 weeks' gestation at birth)
- Intervention: Any of the following: increased room temperature ≥23.0°C, thermal mattress, plastic bag or wrap, hat, heating and humidification of gases used for resuscitation, radiant warmer (with or without servo control), early monitoring of temperature, warm bags of fluid, swaddling, skin-to-skin care with mother, or combinations of these interventions
- Comparators: Drying alone or with use of a plastic bag or wrap, or comparisons between interventions
- Outcomes:
  - Critical: Survival to hospital discharge
  - Important: Rate of normothermia; moderate hypothermia; cold stress; hyperthermia; body temperature; response to resuscitation (need for assisted ventilation, highest Fio_2); major morbidity, including bronchopulmonary dysplasia, intraventricular hemorrhage (all grades), and severe (critical); necrotizing enterocolitis; respiratory distress syndrome; and late-onset sepsis
  - For this review, the definitions in Table 17 were used.[226]
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Unpublished studies were excluded.
- Time frame: No date restrictions were placed on the search. The literature search was updated to July 20, 2022. All years and all languages were included as long as there was an English abstract.

Consensus on Science

The SysRev identified 25 studies. Of these, 18 RCTs including 4516 participants and 7 observational studies provided data that could be extracted to evidence tables (for various comparisons between interventions) for the review.[222,227–249] Of the 13 comparisons from RCTs and 10 from observational studies for which evidence tables were developed, 5 comparisons provided sufficient data to inform the development of treatment recommendations. The studies were conducted in high-, middle-, and low-income countries, but few interventions were studied in all settings. None of the studies included out-of-hospital births. Temperature outcomes were reported in a wide variety of ways, constraining the meta-analysis. Except for the use of a plastic bag or wrap, there were insufficient data for the studied interventions to perform any of the prespecified subgroup analyses.

Comparison 1: Increased Room Temperature ≥23.0°C Versus Lower Room Temperature

Two RCTs[250,251] and 3 observational studies[222,252,253] addressed whether higher ambient temperature versus lower ambient temperature contributed to maintaining normal temperature in preterm infants. Because of heterogeneity, no meta-analysis was performed. A narrative summary of the comparison of room temperature ≥23.0°C and lower room temperature is shown in Table 18. Additional outcomes are included in the full online CoSTR.[225]

Comparison 2: Thermal Mattress Versus No Thermal Mattress

The SysRev found 4 RCTs[230,235,237,243] and 5 observational studies[232,234,237,240,244] that examined the use of a thermal mattress. Data relating to the key critical and important outcomes for the comparison with no thermal mattress are summarized in Table 19. Additional outcomes (and those related to the comparison of a thermal mattress to

Table 17. Definitions

Normothermia	Body temperature 36.5°C–37.5°C	Measured with a digital, mercury, or contactless thermometer (axillary, rectal, or other defined site) on admission to a postnatal ward or neonatal unit; or if admission temperature not reported, temperature measured between 30–60 min of age
Moderate hypothermia	Body temperature 32.0°C–35.9°C	
Cold stress	Body temperature 36.0°C–36.4°C	
Hyperthermia	Body temperature >37.5°C	

a plastic bag or wrap[235,243]) are included in the full online CoSTR.[225]

Comparison 3: Plastic Bag or Wrap Versus No Plastic Bag or Wrap

The SysRev found 15 RCTs including 1831 infants for this comparison.[227–229,231,233,241,242,245,247–249,254–257] Data relating to the key critical and important outcomes are summarized in Table 20. A subgroup analysis by gestational age suggested that a plastic bag or wrap was more effective in preventing moderate hypothermia in high-income countries and in infants born at <28 weeks' gestation compared with those born at 28 to 33+6 weeks; however, the clinical significance of these results is uncertain. Evidence for additional outcomes evaluated is included in the full online CoSTR.[225]

Comparison 4: Cap Versus No Cap

The SysRev found a 3-arm RCT that compared use of a plastic cap (placed on the head, similar to a shower cap) with use of a plastic bag covering the body (no cap, only head dried) or with no plastic cap or bag.[247] Data relating to the key critical and important outcomes for the comparison between use of the plastic cap versus no plastic cap (or bag) are summarized in Table 21. Additional outcomes are included in the full online CoSTR.

For the important adverse outcome of hyperthermia (>37.5°C), there were no events in either arm of the study.[247]

A retrospective observational study of 1764 infants compared the use of various interventions that included use of a plastic bag or wrap, a cloth (linen or woolen) cap, and a transport incubator. After adjustment for key variables, not using a cloth cap was an independent risk factor for hypothermia <36.0°C on neonatal ICU (NICU) admission (aOR, 0.55 [95% CI, 0.39–0.78]).[222]

Comparison 5: Heating and Humidification of Gases Used for Resuscitation Versus No Heating and Humidification

The SysRev found 2 RCTs including 476 infants and 1 observational study including 112 infants. Data relating to the key critical and important outcomes are summarized in Table 22. Additional outcomes and data for the observational study are included in the full online CoSTR.[225]

Comparison 6: Radiant Warmer (With or Without Servo Control)

No studies were found that compared the use of a radiant warmer with no radiant warmer. The only included study was an RCT that compared a servo-controlled radiant warmer with manual control. Data relating to the key critical and important outcomes are summarized in Table 23. Additional outcomes are included in the full online CoSTR.[225]

For the following comparisons or for any combination of these interventions, the SysRev found no RCTs or evaluable observational studies:

- Comparison 7: Early monitoring of temperature versus first measurement on admission
- Comparison 8: Warm bags of fluid versus no warm bags of fluid
- Comparison 9: Swaddling versus no swaddling

Table 18. Increased Room Temperature ≥23.0°C Versus Lower Room Temperature for Birth of Newborn Infants Born at <34 Weeks' Gestation

Comparison	Participants (studies), n	Certainty of evidence (GRADE)	Results
Operating room temperature 20°C vs 23°C	22 (subgroup analysis, 1 RCT)[250]	Very low	Benefit or harm not excluded for any outcome
Higher (24°C–26°C) vs lower (20°C–23°C) DR temperature	91 (1 RCT)[251]	Very low	Increased body temperature on admission (MD, 0.5°C higher [95% CI, 0.15–0.85 higher]) Reduced moderate hypothermia (RR, 0.51 [95% CI, 0.32–0.80]; RD, 337 fewer infants per 1000 were hypothermic [95% CI, 467–137 fewer infants])
Higher (25°C–28°C) vs lower (20°C) operating room temperature	108 (1 cohort study)[253]	Very low	Hypothermia less common when operating room temperatures were higher (RR, 0.69 [95% CI, 0.51–0.94])
DR temperature <25°C vs higher temperature	1764 (1 retrospective observational study)[222]	Very low	DR temperature <25°C independently associated with risk of hypothermia (aOR, 1.44 [95% CI, 1.10–1.88])
High (34°C) vs lower (28°C) ambient temperature	202 (1 observational study)[252]	Very low	Higher admission temperatures (MD, 0.4°C higher [95% CI, 0.24–0.5 higher]) Increased risk of hyperthermia (RR, 11.48 [95% CI, 1.54–85.54]; RD, 115 more infants were hyperthermic per 1000 [95% CI, 6–929 more infants])

aOR indicates adjusted odds ratio; DR, delivery room; GRADE, Grading of Recommendations Assessment, Development and Evaluation; MD, mean difference; RCT, randomized controlled trial; RD, risk difference; and RR, risk ratio.

Table 19. Thermal Mattress Compared With No Thermal Mattress for Newborn Infants Born at <34 Weeks' Gestation

Outcomes (importance)	Participants (studies), n	Certainty of evidence (GRADE)	RR (95% CI)	Anticipated absolute effect	
				Risk or mean with no thermal mattress	RD or MD with thermal mattress (95% CI)
Survival (critical)	174 (2 RCTs)[230,236]	Low	1.02 (0.98–1.06)	929/1000	19 more infants surviving per 1000 (19 fewer to 56 more)
Normothermia on admission (important)	72 (1 RCT)[236]	Moderate	0.53 (0.34–0.81)	771/1000	363 fewer normothermic infants per 1000 (509 fewer to 147 fewer); NNTH, 3 infants
Mean body temperature (important)	174 (2 RCTs)[230,236]	Low	Not applicable	36.3°C	MD 0.46°C higher (0.22 higher to 0.69°C higher)
Hyperthermia (important)	174 (2 RCTs)[230,236]	Low	2.77 (1.24–6.17)	71/1000	126 more hyperthermic infants per 1000 (17 more to 369 more); NNTH, 8 infants
Hyperthermia (important)	703 (4 observational studies)[232,237,240,244]	Moderate	3.44 (1.91–6.20)		113 more hyperthermic infants per 1000 (42 more to 241 more); NNTH, 9 infants

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; MD, mean difference; NNTH, number needed to treat to harm; RCT, randomized controlled trial; RD, risk difference; and RR, risk ratio.

For Comparison 10: skin-to-skin care versus no skin-to-skin care, only 2 small RCTs were identified, and they reported only secondary outcomes.[259,260] Therefore, an evidence-to-decision table and treatment recommendations were not developed. However, good evidence was noted for the benefits of skin-to-skin care for maintaining normal temperature immediately after birth in late preterm and term infants[261] and for maintaining subsequent normal temperature when used soon after birth for low- and very low–birth-weight infants in low- and middle-income countries.[262]

Prior Treatment Recommendations (2015)

Among newly born preterm infants of <32 weeks of gestation under radiant warmers in the hospital delivery room, we suggest using a combination of interventions, which may include environmental temperature 23°C to 25°C, warm blankets, plastic wrapping without drying, cap, and thermal mattress to reduce hypothermia (temperature <36.0°C) on admission to NICU (weak recommendation, very low–quality evidence).

We suggest that hyperthermia (>38.0°C) should be avoided because of the potential associated risks (weak recommendation, very low–quality evidence).

2023 Treatment Recommendations

In preterm infants (<34 weeks' gestation), as for late preterm and term infants (≥34 weeks' gestation), we suggest the use of room temperatures of ≥23°C compared with 20°C at birth in order to maintain normal temperature (weak recommendation, very low–certainty evidence).

In preterm infants (<34 weeks' gestation) immediately after birth, in whom hypothermia on admission is identified as a problem, it is reasonable to consider the addition of a thermal mattress, but there is a risk of hyperthermia (conditional recommendation, low-certainty evidence).

Table 20. Plastic Bag or Wrap Compared With No Plastic Bag or Wrap for Newborn Infants Born at <34 Weeks' Gestation

Outcomes (importance)	Participants (studies), n	Certainty of evidence (GRADE)	RR (95% CI)	Anticipated absolute effect	
				Risk or mean with standard care	RD or MD with plastic bag or wrap
Survival (critical)	1419 (11 RCTs)[227,229,231,233,241,242,245,247–249,255]	High	1.05 (1.00–1.10)	816/1000	41 more infants survived per 1000 (0 fewer to 82 more); NNTB, 24 infants
Normothermia on admission (important)	449 (5 RCTs)[229,233,247,255,256]	Low	2.86 (1.66–4.91)	128/1000	238 more normothermic infants per 1000 (85 more to 501 more); NNTB, 4 infants
Mean body temperature–axillary (important)	755 (10 RCTs)[227,228,231,242,245,247,254–257]	Low	Not applicable	35.6°C	MD 0.65°C higher (0.42°C higher to 0.87°C higher)
Hypothermia or cold stress (important)	489 (6 RCTs)[229,231,233,247,255,256]	Moderate	0.64 (0.50–0.82)	870/1000	313 fewer hypothermic or cold-stressed infants per 1000 (435 fewer to 157 fewer); NNTB, 3 infants
Hyperthermia (important)	817 (9 RCTs)[228,231,241,245,247,249,254–256]	Moderate	3.67 (1.77–7.61)	11/1000	33 more infants were hyperthermic per 1000 (9 more to 81 more); NNTH, 30

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; MD, mean difference; NNTB, number needed to treat to benefit; NNTH, number needed to treat to harm; RCT, randomized controlled trial; RD, risk difference; and RR, risk ratio.

Table 21. Use of Plastic Cap Compared With No Cap for Newborn Infants Born at <34 Weeks' Gestation

Outcomes (importance)	Participants (studies), n	Certainty of evidence (GRADE)	RR (95% CI)	Anticipated absolute effect	
				Risk or mean with standard care	RD or MD with plastic cap
Survival (critical)	64 (1 RCT)[247]	Moderate	0.97 (0.84–1.12)	938/1000	28 fewer infants survived per 1000 (150 fewer to 113 more infants)
Normothermia (important)	64 (1 RCT)[247]	Moderate	6.00 (1.96–18.38)	94/1000	469 more normothermic infants per 1000 (90 more to 1629 more); NNTB, 2 infants
Mean body temperature–axillary (important)	64 (1 RCT)[247]	Moderate	Not applicable	35.3°C	MD, 0.8°C higher (0.41°C higher to 1.19°C higher)
Hypothermia or cold stress (important)	64 (1 RCT)[247]	Moderate	0.48 (0.32–0.73)	906/1000	471 fewer hypothermic or cold-stressed infants per 1000 (616 fewer to 245 fewer); NNTB, 2 infants

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; MD, mean difference; NNTB, number needed to treat to benefit; RCT, randomized controlled trial; RD, risk difference; and RR, risk ratio.

In preterm infants (<34 weeks' gestation) immediately after birth, we recommend the use of a plastic bag or wrap to maintain normal temperature (strong recommendation, moderate-certainty evidence).

Temperature should be carefully monitored and managed to prevent hyperthermia (good practice statement).

In preterm infants (<34 weeks' gestation) immediately after birth, we suggest the use of a head covering to maintain normal temperature (strong recommendation, moderate-certainty evidence).

In preterm infants (<34 weeks' gestation) immediately after birth, we suggest that heated and humidified gases for respiratory support in the delivery room can be used when an audit shows that admission hypothermia is a problem and resources allow (conditional recommendation, very low–certainty evidence).

In preterm infants (<34 weeks' gestation) immediately after birth, there is insufficient published evidence to suggest for or against the use of a radiant warmer in servo-controlled mode compared with manual mode for maintaining normal temperature.

In preterm infants (<34 weeks' gestation), there is insufficient published evidence to suggest for or against the use of skin-to-skin care immediately after birth. Skin-to-skin care may be helpful for maintaining normal temperature when few other effective measures are available (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website, and the evidence-to-decision table is provided in Appendix A.[225] Key discussion points included the following:

- For ambient temperature, some of the evidence was indirect from a study that included late preterm and term infants.[250] The safe upper limit of room temperature was not identified, and it may also be affected by ambient humidity.
- For plastic bags or wraps, which have been recommended by ILCOR since 2010,[263] the evidence of benefit for survival is now of high certainty, and their

Table 22. Heating and Humidification of Gases for Resuscitation Compared With No Heating and Humidification of Gases for Newborn Infants Born at <34 Weeks' Gestation

Outcomes (importance)	Participants (studies), n	Certainty of evidence (GRADE)	RR (95% CI)	Anticipated absolute effect	
				Risk or mean with standard care	RD or MD with heated and humidified gases
Survival (critical)	476 (2 RCTs)[238,239]	Very low	1.00 (0.94–1.05)	918/1000	0 fewer/more infants survived per 1000 (55 fewer to 56 more)
Normothermia on admission (important)	476 (2 RCTs)[238,239]	Very low	1.23 (0.93–1.62)	471/1000	108 more infants were normothermic per 1000 (33 fewer to 292 more)
Mean axillary body temperature (important)	476 (2 RCTs)[238,239]	Moderate	Not applicable	36.6°C	MD 0.15°C higher (0.03°C higher to 0.26°C higher)
Moderate hypothermia	476 (2 RCTs)[238,239]	Low	0.58 (0.36–0.94)	172/1000	72 fewer hypothermic infants per 1000 (68 fewer to 7 fewer); NNTB, 14 infants
IVH above grade 2	476 (2 RCTs)[238,239]	Moderate	0.39 (0.17–0.91)	82/1000	50 fewer infants had IVH per 1000 (68 fewer to 7 fewer); NNTB, 42 infants

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; IVH, intraventricular hemorrhage; MD, mean difference; NNTB, number needed to treat to benefit; RCT, randomized controlled trial; RD, risk difference; and RR, risk ratio.

Note: Gases refers to air and oxygen (reticulated or from cylinders).

Table 23. Servo Control of Radiant Warmer Compared With Manual Control for Infants Born at <34 Weeks' Gestation

Outcomes (importance)	Participants (studies), n	Certainty of evidence (GRADE)	RR (95% CI)	Anticipated absolute effect	
				Risk or mean with manual control	RD or MD with servo control
Survival (critical)	450 (1 RCT)[258]	Moderate	1.05 (0.99–1.11)	884/1000	44 more infants survived per 1000 (9 fewer to 97 more)
Normothermia on admission (important)	450 (1 RCT)[258]	Moderate	0.94 (0.75–1.17)	422/1000	25 fewer normothermic infants per 1000 (106 fewer to 72 more)
Mean body temperature (important)	450 (1 RCT)[258]	Moderate	Not applicable	36.5°C	MD 0.2°C lower (0.33°C lower to 0.07°C lower)
Hypothermia or cold stress	450 (1 RCT)[258]	Moderate	1.20 (1.01–1.42)	498/1000	100 more hypothermic or cold-stressed infants per 1000 (5 more to 209 more); NNTH, 2 infants

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; MD, mean difference; NNTH, number needed to treat to harm; RCT, randomized controlled trial; RD, risk difference; and RR, risk ratio.

use is considered standard of care in many neonatal services. They were considered feasible to use in low- and high-resource settings, including for out-of-hospital births.

- For head coverings, the only evidence from an RCT related to use of a plastic cap. Evidence from an observational study[222] and indirect evidence from studies of late preterm and term infants suggest that caps made of cloth are also likely effective.[261]
- For thermal mattresses, safety warnings exist for risk of hyperthermia and skin burns. Nevertheless, the task force concluded that thermal mattresses can be used with care, primarily when other methods to maintain normal temperature are unavailable or insufficient.
- Larger studies reporting short- and longer-term outcomes are needed to determine the role of heated and humidified gases for newborn resuscitation. Although their use for assisted ventilation is regarded as routine during subsequent neonatal intensive care, providing them for every birth at <34 weeks' gestation is likely to be unaffordable in many settings. A conditional recommendation was therefore developed.
- A common theme across comparisons was that each study examined the relevant intervention in the context of multiple cointerventions that may have affected the reported effect size. Indeed, it is likely that a bundle of interventions operating through different mechanisms is needed for most preterm infants. However, the review did not identify sufficient evidence for any specific bundle. The design of such bundles should be based on the certainty of evidence for each intervention in addition to the availability of resources and local environmental considerations.
- The risk of harm from hyperthermia is likely to be higher when multiple interventions are used concurrently. Early measurement of temperature may detect when additional measures are needed for individual infants, and regular audit is needed to ensure that strategies achieve maintenance of normal temperature for most infants.

Task Force Knowledge Gaps

- Whether specific bundles of interventions are beneficial to maintain normal temperature compared with other specific bundles
- How ambient temperature and humidity affect the effectiveness of any means to maintain normal temperature
- Cost-effectiveness of any of the interventions studied
- The optimal set temperatures for the operating theater and other delivery room settings
- The role of thermal mattresses for births in prehospital settings when other devices and methods for maintaining normal temperature are unavailable
- The risks and benefits of using head coverings composed of different materials
- Whether the use of heated and humidified gases during resuscitation reduces lung injury or severe intraventricular hemorrhage
- The role of servo control in maintaining normal temperature in preterm infants requiring prolonged resuscitation
- Whether servo-controlled devices could be adapted for use during deferred cord clamping
- Whether the efficacy of a radiant warmer used in servo-controlled mode depends on the position of the temperature sensor probe
- What other interventions to maintain normal temperature are effective (and can be safely adapted) for use during skin-to-skin care

Heart Rate Monitoring: Diagnostic Characteristics (SysRev)

Rationale for Review

Heart rate is considered one of the most important indicators of an infant's condition at birth. Limitations of assessing heart rate by palpation of pulses or by pulse

oximetry were identified in a 2015 ILCOR SysRev, which found that electrocardiography was faster and more accurate.[221] A 2020 EvUp found studies using newer devices and methods.[264] A 2022 ILCOR SysRev found little evidence to suggest improvement in critical and important clinical outcomes with the use of electrocardiography compared with pulse oximetry.[58] However, heart rate influences critical decisions about resuscitation at birth, so a SysRev was conducted to assess the diagnostic characteristics of various devices and methods for measuring heart rate in the first minutes after birth (PROSPERO registration CRD 42021283364). See the ILCOR website for the full online CoSTR.[265]

PICOST

- Population: Newborn infants in the delivery room
- Intervention: Use of auscultation, palpation, pulse oximetry, Doppler device, digital stethoscope, photoplethysmography, video plethysmography, dry electrode technology, or any other newer modalities
- Comparators: ECG or between-method comparisons
- Outcomes:
  - Important: Time to first heart rate assessment from the device placement, time to first heart rate assessment from birth, and accuracy of heart rate assessment

For the purposes of this SysRev, electrocardiographic heart rate was considered the gold standard. Accuracy of heart rate assessment by other methods was examined with the following:

- Pooled Bland-Altman analysis[266–270] to estimate bias, a measure of accuracy, and the limits of agreement, a measure of precision. For the purposes of the review, agreement within ±10 bpm was considered acceptable.
- Pooled sensitivity and specificity analysis to identify electrocardiographic heart rate <100 and <60 bpm

Further details about methods are included in the full online CoSTR.[265]

- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, and cohort studies) were eligible for inclusion.
- Time frame: All years and all languages were included as long as there was an English abstract; unpublished studies (eg, conference abstracts, trial protocols) were excluded. The literature search was updated to August 5, 2022.

Consensus on Science

Comparison 1: Pulse Oximeter Versus Electrocardiography

The SysRev identified 3 RCTs[271–273] including 187 infants and 11 cohort studies[274–284] including 490 infants. Data relating to the key outcomes for the comparison of pulse oximetry and electrocardiography are summarized in Table 24. These results indicate that pulse oximetry is slower and more imprecise than electrocardiography is for heart rate assessment at birth.

Additional outcomes are included in the full online CoSTR.[265]

Comparison 2: Auscultation Compared With Electrocardiography

The SysRev identified 5 observational studies including 171 infants.[275,285–288] Data relating to the key outcomes for the comparison of auscultation and electrocardiography are summarized in Table 25. These results indicate that auscultation may be faster and accurate but is imprecise compared with electrocardiography for heart rate assessment at birth.

Additional outcomes are included in the full online CoSTR.[265]

Comparison 3: Palpation Versus Electrocardiography

The SysRev identified 2 observational studies including 86 infants.[285,286] Data relating to the key outcomes for the comparison of palpation with electrocardiography are summarized in Table 26. These results indicate that

Table 24. Pulse Oximetry Compared With Electrocardiography for Measuring HR at Birth: Diagnostic Characteristics

Outcomes	Participants (studies), n	Certainty of evidence (GRADE)	Pooled median difference or bias	MD (95% CI) or LoA (95% CI)
Time to first HR from device placement	136 (2 RCTs)[272,273]	Very low	12 s slower	38 s slower to 13 s faster
	323 (6 observational studies)[274,276,279,280,282,284]	Low	57 s slower	101 s slower to 13 s slower
Time to first HR from birth	87 (2 RCTs)[271,273]	Low	6 s slower	23 s slower to 10 s faster
	334 (6 observational studies)[274,275,277,283–285]	Low	52 s slower	94 s slower to 9 s slower
Accuracy of HR assessment	216 infants (1 RCT, 4 observational studies 28 211 observations)[271,277,278,281,284]	Moderate	HR_{PO}–HR_{ECG}, −1.2 bpm	LoA, −17.9 to 15.5 bpm (95% CI, −32.8 to 30.4)
Accuracy of HR assessment (sensitivity and specificity of pulse oximetry for HR <100 bpm)	124 (3 studies)[271,279,281] 8342 observations	Very low	Sensitivity, 0.83 (95% CI, 0.76 to 0.88) Specificity, 0.97 (95% CI, 0.93 to 0.99)	

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; HR, heart rate; HR_{ECG}, heart rate measured with electrocardiography; HR_{PO}, heart rate measured with pulse oximetry; LoA, limits of agreement; and RCT, randomized controlled trial.

Table 25. Auscultation Compared With Electrocardiography for Measuring HR at Birth: Diagnostic Characteristics

Outcomes	Participants (studies), n	Certainty of evidence (GRADE)	Pooled median difference or bias	95% CI or LoA (95% CI)
Time for first HR from device placement	105 (3 observational studies)[275,287,288]	Moderate	4 s faster	10 s faster to 2 s slower
Time for first HR from birth	70 (2 observational studies)[275,288]	Low	24 s faster	45 s faster to 2 s faster
Accuracy of HR assessment	71 (2 observational studies)[285,287]	Low	HR_{aus} − HR_{ECG}, −9.9 bpm	LoA, −32 to 12 bpm (95% CI, −217 to 198)

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; HR, heart rate; HR_{aus}, heart rate measured with auscultation; HR_{ECG}, heart rate measured with electrocardiography; and LoA, limits of agreement.

palpation is inaccurate and imprecise compared with electrocardiography for heart rate assessment at birth.

Additional outcomes are included in the full online CoSTR.[265]

Some studies were also found for each of the following comparisons, and the evidence is included in the full online CoSTR.[265] None of the evidence was considered sufficient to develop treatment recommendations:

- Comparison 4: Palpation compared with auscultation
- Comparison 5: Digital stethoscope compared with electrocardiography
- Comparison 6: Doppler ultrasound compared with electrocardiography
- Comparison 7: Dry electrodes incorporated into a belt compared with (conventional 3-lead) electrocardiography

Prior Treatment Recommendations

2015: In babies requiring resuscitation, we suggest that electrocardiography can be used to provide a rapid and accurate estimation of heart rate (weak recommendation, very low–quality evidence).

2022: When resources permit, we suggest that the use of electrocardiography for heart rate assessment of a newborn infant requiring resuscitation in the delivery room is reasonable (weak recommendation, low-certainty evidence).

When electrocardiography is not available, auscultation with pulse oximetry is a reasonable alternative for heart rate assessment, but the limitations of these modalities should be kept in mind (weak recommendation, low-certainty evidence).

There is insufficient evidence to make a treatment recommendation for the use of digital stethoscope, audible or visible Doppler ultrasound, dry electrode technology, reflectance-mode green light photoplethysmography, or transcutaneous electromyography of the diaphragm for heart rate assessment of a newborn in the delivery room.

Auscultation with or without pulse oximetry should be used to confirm the heart rate when electrocardiography is unavailable or is not functioning or when pulseless electrical activity is suspected (good practice statement).

2023 Treatment Recommendations

When accurate heart rate estimation is needed for a newborn infant immediately after birth and resources permit, we suggest that the use of electrocardiography is reasonable (conditional recommendation, low-certainty evidence).

Pulse oximetry and auscultation may be reasonable alternatives to electrocardiography for heart rate assessment, but the limitations of these modalities should be kept in mind (conditional recommendation, low-certainty evidence).

There is insufficient evidence to make a treatment recommendation for the use of any other device for heart rate assessment of a newborn infant immediately after birth.

Auscultation with or without pulse oximetry should be used to confirm the heart rate when electrocardiography is unavailable or is not functioning or when pulseless electrical activity is suspected (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website,[265] and the evidence-to-decision table is provided in Appendix A. Key points of discussion include the following:

- The treatment recommendations reflect the results of both this review and the 2022 ILCOR SysRev of clinical outcomes of different methods of heart rate assessment.[58]
- The available data suggest that electrocardiography provides a more rapid and accurate assessment of heart rate in the delivery room compared with pulse

Table 26. Palpation Compared With Electrocardiography for Measuring HR at Birth: Diagnostic Characteristics

Outcomes	Participants (studies), n	Certainty of evidence (GRADE)	Mean±SD	MD±SEM
Accuracy of HR assessment	21 (1 observational study)[285]	Very low	HR_{palp} 147±19 bpm vs HR_{ECG} 168±22 bpm	−21±21 bpm

GRADE indicates Grading of Recommendations Assessment, Development, and Evaluation; HR, heart rate; HR_{ECG}, heart rate measured with electrocardiography; HR_{palp}, heart rate measured with palpation; and MD, mean difference.

oximetry and more accurate assessment than palpation or auscultation, but the certainty of evidence ranges from moderate to very low.
- Most studies did not include the infants in whom rapid, accurate assessment of heart rate may be most important, for example, infants who were bradycardic, were requiring resuscitation, or were extremely premature. The companion SysRev that assessed clinical outcomes[58] found that it is unclear whether rapidity, accuracy, and precision of heart rate estimation at birth result in clinically relevant differences in resuscitation interventions, resuscitation team performance, or clinical outcomes for newborn infants.
- Auscultation, pulse oximetry, or both have been routinely used for heart rate assessment in newborns at birth. When resources are limited, the addition of another device may be impractical or unaffordable.

Task Force Knowledge Gaps

- More data are needed on the characteristics of measurement of heart rate in the delivery room with devices such as digital stethoscope, Doppler ultrasound (audible or visible displays), reflectance-mode green light photoplethysmography, or devices detecting electrocardiography using dry electrodes. Such studies should include evaluation of time to first heart rate assessment from birth and from device placement.
- Cost-effectiveness of different modalities for heart rate assessment in the delivery room
- Impact of different heart rate assessment methods on resuscitation team performance, resuscitation interventions, and neonatal clinical outcomes
- Evidence as to whether different devices are better suited to different subgroups of infants (eg, by gestation or by anticipated need for advanced resuscitation)

Exhaled CO_2 Detection to Guide Noninvasive Ventilation (SysRev)

Rationale for Review

ILCOR has previously evaluated the use of CO_2 monitoring to confirm correct placement of tracheal tubes (colorimetric devices) and during invasive ventilation to improve CO_2 levels on admission to a neonatal unit, but these reviews did not include a GRADE evaluation.[263] CO_2 monitoring devices have also been systematically reviewed (as part of a review of several feedback devices) in newborn infants for detecting ROSC.[221] More recent studies have examined the use of CO_2 detection to guide noninvasive ventilation at birth, the focus of the current review. A SysRev was initiated from a priority list from the ILCOR NLS Task Force (PROSPERO registration CRD42022344849). See the ILCOR website for the full online CoSTR.[289]

PICOST

- Population: Newborn infants receiving intermittent positive-pressure ventilation (IPPV) by any noninvasive interface at birth
- Intervention: Use of exhaled CO_2 monitor in addition to clinical assessment, pulse oximetry, or electrocardiography
- Comparators: Clinical assessment, pulse oximetry, or electrocardiography only
- Outcomes:
  - Critical: Survival
  - Important: Tracheal intubation in the delivery room, other resuscitation outcomes at birth, other major morbidities, and unexpected admission to special or ICU in infants born at ≥34 weeks' gestation.
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, and cohort studies) were eligible for inclusion. Case series, case reports, animal studies, and unpublished studies (conference abstracts, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to August 1, 2022.

Consensus on Science

The SysRev identified 23 studies that addressed the use of CO_2 monitoring during noninvasive IPPV. In only 8 of these (including 419 infants) were CO_2 detection devices or monitor displays visible to those performing the resuscitation.[290–297] The devices for positive-pressure ventilation varied (T-piece device, self-inflating bag, flow-inflating bag), but the interface in all studies was a face mask. None of the studies were designed to address the PICOST question, and differences in study design precluded any meta-analysis. The following sections summarize the findings of a narrative review of these studies; further description is included in the full online CoSTR.[289]

Exhaled CO_2 Monitoring and Airway Obstruction

Two observational studies including 59 preterm infants described continuous use of a colorimetric CO_2 detection device during noninvasive IPPV and recorded that health care professionals responded to its display with corrective actions.[290,292]

Exhaled CO_2 to Assess Lung Aeration

One RCT of sustained inflation including 162 infants[297] and 2 observational studies together including 95 infants[291,294] suggested that monitoring of exhaled CO_2 is feasible (including while providing face mask IPPV during delayed umbilical cord clamping[291]) and that a rise in exhaled CO_2 correlates with improvements in lung aeration.

Exhaled CO_2 as a Predictor of Increase in Heart Rate in Initially Bradycardic Infants

One observational study including 41 bradycardic preterm infants concluded that a change in a colorimetric CO_2 detector device precedes a clinically significant increase in heart rate.[290] A second study including 7 infants found that an exhaled CO_2 level >15 mm Hg preceded a clinically significant increase in heart rate.[296]

Exhaled CO_2 and Pco_2 at NICU Admission

One RCT including 37 preterm infants born at <34 weeks' gestation compared a visible with a masked CO_2 monitor and found no difference in the proportion of infants with Pco_2 in the target range on NICU admission.[295] One RCT including 59 infants born at <32 weeks' gestation compared quantitative and qualitative CO_2 monitoring and found no differences in Pco_2 in the target range on NICU admission.[293]

Prior Treatment Recommendations

None

2023 Treatment Recommendation

There is insufficient evidence to suggest for or against the use of exhaled CO_2 to guide noninvasive IPPV with noninvasive interfaces such as face masks, supraglottic airways, and nasal cannulas in infants immediately after birth.

Justification and Evidence-to-Decision Framework Highlights

The evidence-to-decision table for this topic can be found in Appendix A, and the full text of the evidence-to-decision highlights is on the ILCOR website.[289] Key discussion points included the following:

- There were no studies in infants receiving noninvasive IPPV in the delivery room that compared use of CO_2 monitoring (using quantitative or qualitative devices) with no device or a masked device that demonstrated improvement in any clinical outcome. The combined studies did suggest that both types of devices are feasible to use, that they may assist with detection of airway obstruction and other causes of inadequate lung aeration and ventilation, and that increases in exhaled CO_2 precede improvements in heart rate in bradycardic infants.
- Concerns about the use of quantitative and qualitative exhaled CO_2 monitoring devices to improve noninvasive IPPV include the potential for misinterpretation; it may not be possible to differentiate inadequate tidal ventilation from very low pulmonary blood flow as a cause for low exhaled CO_2, and dead space ventilation (physiological or equipment related) could lead to overestimation of exhaled CO_2.
- The reliability of colorimetric CO_2 devices may be affected by contamination with gastric contents or medications.[290,298]

Task Force Knowledge Gaps

- The efficacy and effectiveness of different devices for CO_2 monitoring to guide noninvasive IPPV via face mask or supraglottic airway device in newborns immediately after birth for infants of various birthweights in various clinical settings
- The optimal range for exhaled CO_2 in each minute after birth
- The effect of gastric reflux, other secretions, blood, meconium, or medications on the reliability of colorimetric CO_2 detectors
- The potential for CO_2 monitoring to distract or bias health care professionals
- Cost-effectiveness of CO_2 monitoring

Heart Rate to Initiate Chest Compressions (ScopRev)

Rationale for Review

The recommended heart rate threshold for initiating chest compressions during resuscitation at birth has been <60 bpm since 1999; at the same time, the optimal heart rate threshold for initiating chest compressions has been identified as a gap in knowledge.[299] A ScopRev was initiated from a priority list from the ILCOR NLS Task Force.[300] See the ILCOR website for the full online CoSTR.[301]

PICOST

- Population: Newborn infants immediately after birth who are being resuscitated with ventilation and who have a slow heart rate
- Intervention: Starting cardiac compressions at other heart rate thresholds
- Comparators: Starting cardiac compressions when the heart rate is <60 bpm
- Outcomes:
  - Critical: survival, neurological outcomes
  - Important: Any other reported short- or long-term outcomes, including time to ROSC
- Study designs: RCTs, nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies), and case series were eligible for inclusion. Manikin, computer model, and animal studies were eligible for inclusion. Conference abstracts and unpublished studies (eg, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to November 22, 2021.

Summary of Evidence

No studies were found that examined different heart rate thresholds for initiating chest compressions in newborn infants immediately after birth. There is also very little evidence from animal studies.[302] Further description is included in the full online CoSTR.[301]

Task Force Insights

The heart rate threshold of <60 bpm was originally selected on the basis of expert opinion and a desire to simplify the resuscitation algorithm. The ScopRev provided no data sufficient to alter the existing recommendation, but the optimal threshold and whether it differs for different subgroups of infants remain unknown.

Treatment Recommendations

ILCOR has not developed an evidence-based treatment recommendation for heart rate threshold to initiate chest compressions previously. However, ILCOR guidance since 1999 has been to initiate chest compressions if the heart rate is <60 bpm despite adequate assisted ventilation for 60 seconds.[299] Insufficient evidence was found in the ScopRev to support a new SysRev or a different recommendation.

Supplemental Oxygen During Chest Compressions (ScopRev)

Rationale for Review

A 2015 ILCOR SysRev examined evidence for 100% O_2 as the ventilation gas during chest compressions compared with lower concentrations of O_2 and concluded that there were no human data to inform this question.[221] Surveillance of resuscitation literature suggested that there may be more recent studies, including indirect evidence from animal models. A ScopRev was initiated from a priority list from the ILCOR NLS Task Force.[300] See the ILCOR website for the full online CoSTR.[303]

PICOST

- Population: Newborn infants immediately after birth who received chest compressions
- Intervention: Any lower concentrations of O_2
- Comparators: 100% O_2 as the ventilation gas
- Outcomes:
  - Critical: Survival, neurological outcomes
  - Important: Any other reported short- or long-term outcomes, including time to ROSC
- Study designs: RCTs, nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies), and case series were eligible for inclusion. Manikin, computer model and animal studies were also eligible for inclusion. Conference abstracts and unpublished studies (eg, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to November 22, 2021.

Summary of Evidence

No human studies that compared any other oxygen concentration with 100% O_2 during chest compressions were identified. Six animal studies comparing 21% with 100% inspired O_2 concentrations during chest compressions after asphyxial cardiac arrest were identified. Overall, they found no differences in time to ROSC, mortality, inflammation, or oxidative stress.[304–309] Further description is included in the full online CoSTR.[303]

Task Force Insights

The available evidence from animal studies suggests that resuscitation using 21% O_2 during chest compressions is feasible and results in similar short-term outcomes. However, the animal studies examined only asphyxia-induced asystole of brief duration in animals lacking other underlying pathological conditions, and there are no human infant data. The available evidence was insufficient to warrant a new SysRev or to suggest the need to alter the current treatment recommendation.

Treatment Recommendations

The 2015 good practice statement remains unchanged:

Despite animal evidence showing no advantage to the use of 100% oxygen, by the time resuscitation of a newborn infant has reached the stage of chest compressions, the steps of trying to achieve ROSC using effective ventilation with low-concentration oxygen should have been attempted. Thus, it would seem prudent to try increasing the supplementary oxygen concentration (good practice statement).[221]

American Heart Association.

Neonatal Chest Compression Technique (Other Techniques Versus 2-Thumb Technique; ScopRev)

Rationale for Review

A 2015 ILCOR SysRev examined evidence for a 2-thumb technique compared with a 2-finger technique for neonatal chest compressions and recommended a 2-thumb technique on the basis of very low–certainty evidence from nonrandomized studies and a single manikin study.[221] Surveillance of resuscitation literature identified more recent studies examining other techniques. A ScopRev was initiated from a priority list from the ILCOR NLS Task Force and has been published.[300] See the ILCOR website for the full online CoSTR.[310]

PICOST

- Population: Newborn infants immediately after birth who received chest compressions
- Intervention: Use of any other technique (2-finger or other technique) for chest compressions
- Comparator: 2-thumb technique for chest compressions
- Outcomes:
  - Critical: Survival and neurological outcomes
  - Important: Any other reported short- or long-term outcomes, including time to ROSC
- Study designs: RCTs, nonrandomized studies (non-RCTs, interrupted time series, controlled

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before-and-after studies, cohort studies), and case series were eligible for inclusion. Manikin, computer model, and animal studies were also eligible for inclusion. Conference abstracts and unpublished studies (eg, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to November 22, 2021.

Summary of Evidence

The current ScopRev identified 29 randomized crossover manikin studies, 1 observational study, and 1 randomized study comparing various finger/hand positions.[311–340]

The available data confirmed that the 2-thumb technique resulted in greater chest compression depth, lower fatigue, and higher proportion of correct hand placement compared with the 2-finger technique. No alternative finger or hand position techniques resulted in overall better performance measures compared with the 2-thumb technique. Further description is included in the full online CoSTR.[310]

Task Force Insights

The information from the studies identified was considered insufficient to warrant a SysRev or to alter existing recommendations.

Treatment Recommendations

The 2015 treatment recommendation remains unchanged.

We suggest that chest compressions in newborn infants immediately after birth should be delivered by the 2-thumb, hands-encircling-the-chest method as the preferred option (weak recommendation, very low–quality evidence).

Compression-to-Ventilation Ratio for Neonatal CPR (ScopRev)

Rationale for Review

The 2015 CoSTR and a subsequent EvUp suggested continuing to use a 3:1 compression-to-ventilation ratio.[221,264] There was no evidence from human infants for this ratio, and it was based on animal and manikin studies. However, the EvUp identified sufficient new animal and manikin studies and 1 small clinical trial to justify inclusion in the multifaceted ScopRev of questions related to chest compressions. A ScopRev was initiated from a priority list from the ILCOR NLS Task Force.[300] See the ILCOR website for the full online CoSTR.[341]

PICOST

- Population: Newborn infants immediately after birth who received chest compressions
- Intervention: Any other compression-to-ventilation ratio (5:1, 9:3, 15:2, asynchronous)
- Comparators: 3:1 compression-to-ventilation ratio
- Outcomes:
  - Critical: Survival and neurological outcomes
  - Important: Any other reported short- or long-term outcomes, including time to ROSC hemodynamic parameters, tissue oxygenation, lung or brain inflammatory markers, and compressor fatigue
- Study designs: RCTs, nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies), and case series were eligible for inclusion. Manikin, computer model, and animal studies were also eligible for inclusion. Conference abstracts and unpublished studies (eg, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to November 22, 2021.

Summary of Evidence

The ScopRev identified 23 studies examining different compression-to-ventilation ratios, continuous chest compressions with asynchronous ventilation, or chest compressions with sustained inflation.[304,305,307,342–361] These studies are summarized in Table 27 and further details are available in the full online CoSTR.[341]

Task Force Insights

The information from the studies identified was considered insufficient to alter the existing recommendation. The task force noted that a larger trial of chest compressions with sustained inflation is underway (ClinicalTrials.gov identifier: NCT02858583).

Treatment Recommendations

The 2015 treatment recommendation remains unchanged.

We suggest continued use of a 3:1 compression-to-ventilation ratio for CPR in newborn infants immediately after birth (weak recommendation, very low–certainty evidence).

Use of Feedback CPR Devices for Neonatal Cardiac Arrest (ScopRev)

Rationale for Review

The use of feedback devices such as end-tidal carbon dioxide ($ETCO_2$) monitors, pulse oximeters, or automated compression feedback devices was considered in an ILCOR 2015 SysRev.[221] Surveillance of resuscitation literature suggested that there may be more recent studies, including indirect evidence from animal models. A ScopRev was initiated from a priority list from the ILCOR NLS Task Force.[300] See the ILCOR website for the full online CoSTR.[362]

Table 27. Chest Compression–to–Ventilation Ratio for Neonatal Resuscitation

Compression-to-ventilation ratio	2 RCTs, manikin studies[346,359]	3:1 vs 5:1 vs 15:2 ratios; 3:1 was associated with more consistent CC depth and preferred by rescuers.[346] No differences in compressor fatigue among 3:1, 5:1, 10:2, 15:2 ratios, but 3:1 rated more difficult[359]
	5 RCTs, piglet studies[304,305,307,352,357]	No differences in time to ROSC, survival, biomarkers of brain or organ injury between various ratios, including 3:1, 9:3, 15:2, 2:1, and 4:1
Continuous CC with asynchronous ventilation	5 RCTs, manikin studies[343–345,347,358]	Variable results but some studies found greater fatigue and lower CC depth with continuous CC with asynchronous ventilation vs 3:1 compression-to-ventilation ratio
	6 RCTs, piglets (5) or lambs (1)[342,349,350,353,355,361]	For time to ROSC and for survival, 1 RCT found improvements with continuous CC with asynchronous ventilation vs 3:1 compression-to-ventilation ratio. One RCT found improved physiological measures with CC with asynchronous ventilation vs 3:1 compression-to-ventilation ratio.
CC with sustained inflation	4 RCTs, piglets (3) or lambs (1)[348,351,360]	Faster time to ROSC but similar survival with CC combined with repeated 20-s sustained inflations vs 3:1 compression-to-ventilation ratio
	1 RCT, human infants[354]	Faster time to ROSC with CC combined with repeated 20-s sustained inflations vs 3:1 compression-to-ventilation ratio

CC indicates chest compressions; RCT, randomized controlled trial; and ROSC, return of spontaneous circulation.

PICOST

- Population: Newborn infants immediately after birth who received chest compressions
- Intervention: Use of any feedback devices such as $ETCO_2$ monitors, pulse oximeters, or automated compression feedback devices
- Comparators: Clinical assessments of compression efficacy
- Outcomes:
  - Critical: Survival and neurological outcomes
  - Important: Hands-off time, time to ROSC, and perfusion
- Study designs: RCTs, nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies), and case series were eligible for inclusion. Manikin, computer model, and animal studies were also eligible for inclusion. Conference abstracts and unpublished studies (eg, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to November 22, 2021.

Summary of Evidence

The ScopRev identified 18 studies that addressed chest compression feedback devices: 12 manikin studies,[363–373] 4 animal studies,[374–377] and 2 human infant studies.[378,379] Twelve of the studies used randomized allocation to study arms. Most of the manikin studies assessed musical, auditory, tactile, or other signals to improve the cadence of chest compressions, but 1 manikin study tested a decision support tool and other devices that detected chest compression depth and rate. All reported improvements in chest compression rate, consistency, depth, or other measures of quality in the simulation setting, but none reported translation of the device or improvement in skills as a result of using the device into improvements in performance or infant outcomes in clinical settings. All the animal studies tested the role of $ETCO_2$ in improving resuscitation outcomes or in predicting ROSC. No differences were found in ROSC or survival from using $ETCO_2$ to guide chest compressions.[374–377] One of the 2 retrospective human infant studies assessed a practice change to increase depth of chest compressions,[378] and 1 study evaluated $ETCO_2$ as a predictor of ROSC.[379] Details are available in the full online CoSTRs.[362]

Task Force Insights

The body of available evidence does not justify an ILCOR SysRev at this time because no studies assessed whether feedback devices result in improvements in resuscitation practice or outcomes in human infants. Further research is justified, including assessing whether improvements measured in simulation settings result in improvement in clinical performance or outcomes and to assess the role of capnography and other types of clinical measurements in improving outcomes in infants who receive chest compressions.

Treatment Recommendations

The 2015 treatment recommendation remains unchanged.

In newborn infants with asystole or bradycardia, we suggest against the routine reliance on any single feedback device such as $ETCO_2$ monitors or pulse oximeters for detection of ROSC until more evidence becomes available (weak recommendation, very low–certainty evidence).

EDUCATION, IMPLEMENTATION, AND TEAMS

Family Presence in Adult Resuscitation (SysRev)

Rationale for Review

Low survival rates suggest that cardiac arrest is a pivotal event during which family members may wish to be present during resuscitative efforts.[380] Family presence has been advocated to improve coping and grieving outcomes for families, to reduce litigation, and to improve resuscitation

team behaviors.[380–382] Conversely, concerns have been raised about the distress that family presence during resuscitation may cause families or health care professionals, as well as its impact on team performance.[380,383]

In 2021, an ILCOR SysRev of family presence during neonatal and pediatric resuscitation was conducted.[384] The current SysRev was undertaken on behalf of the Education, Implementation, and Teams (EIT), BLS, and ALS Task Forces to address this question in the adult population (PROSPERO registration CRD4202124238400).[385] The full online CoSTR can be found on the ILCOR website.[386]

PICOST

- Population: Adults requiring resuscitation for cardiac arrest in any setting
- Interventidcxzon: Family presence during resuscitation
- Comparators: Family not present during resuscitation
- Outcomes:
  - Patient outcomes (short and long term): ROSC, survival (to hospital admission, hospital discharge/30 days, 3 months, 6 months, 1 year), survival with good neurological outcomes (at same time points), and depression or anxiety
  - Family (or significant other) outcomes (short and long term): Posttraumatic stress disorder, coping, perception of the resuscitation, depression or anxiety among family members, and complicated grief syndrome
  - Health care professional outcomes: Perception of the resuscitation, performance, perceived futility in some circumstances, and psychological stress, including projection to the health care professional's own family
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were included, and unpublished studies (eg, conference abstracts, trial protocols) were excluded.
- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to May 10, 2022.

Consensus on Science

The 31 studies[387–417] included were highly heterogeneous, comprising a range of study designs, with just over half of all the studies having a qualitative study design and only 2 being RCTs (Table 28).[387,388] Evidence was very low certainty because of potential confounding and heterogeneity or a lack of information on patient, family, health care professional, and cardiac arrest setting characteristics. Evidence was also downgraded for inconsistency in the reporting of results, indirectness in terms of population, study design, and outcomes of interest and imprecision.

Overall, there was no evidence of harm for patients or families from family presence across the studies. However, there was variability in practices and outcomes of family presence during resuscitation; therefore, no meta-analysis was possible.

Table 28. Family Presence During Adult Resuscitation, Study Characteristics

Study designs	Investigated environment
31 studies included[387–417]	24 studies examined in-hospital resuscitation[387,389,390,392–402,404,406,407,409,411–416]
2 randomized controlled trials[387,388]	11 studies in the emergency department[387,393–396,402,409,411–413,417]
16 observational studies[387–404]	5 studies in the ICU[389,398,409,411,416]
12 qualitative studies[405–413,415–417]	5 studies in critical care areas[397,406,412,413,415]
1 mixed-methods study[414]	6 studies in all hospital areas[390,399,404,409,411,414]
	3 studies did not report the specific in-hospital context[392,400,401]
	8 studies reported >1 in-hospital location[397,404,409,411–414,417]
	5 studies reported out-of-hospital resuscitation[388,391,403,405,410]
	1 study reported both in-hospital and out-of-hospital resuscitation[417]
	1 study did not clearly report the context[408]

ICU indicates intensive care unit.

Supplemental Table EIT-S1 summarizes the outcomes on patients, family, and health care professionals when family members are present during resuscitation of adult patients after cardiac arrest.

1. Patient outcomes were reported in 12 studies.[388–392,399,404,406,407,411,414,416] Four studies compared family presence with no family presence.[388–390,404] Only 1 study found higher rates of ROSC and survival to discharge when no family members were present during resuscitation.[389]
2. Family outcomes were reported in 15 studies[387,388,391–395,403,405–408,411,414,416] investigating depression, anxiety, posttraumatic stress disorder, and experience of witnessing the resuscitation of a family member. Whereas 3 studies reported increased rates of depression[391] or posttraumatic stress disorder,[393,403] little evidence was found that witnessing a family member's resuscitation caused one of these mental health conditions.
3. Both positive and negative outcomes were reported when witnessing a family member's resuscitation. Many family members would witness resuscitation again[394,395] because doing so enabled them to better manage their grief.[394] Reported negative outcomes included managing emotional responses,[407] interfering with resuscitation,[407] the dehumanizing nature of resuscitation,[405] and the long,[395] brutal, dehumanizing, and excessive nature of the resuscitation process.[405]
4. Health care professional outcomes were measured in 20 studies.[387,388,394–402,404,409–415,417] Varying experience with family witnessing resuscitation was

evident, and few positive or negative outcomes were reported. Health care professionals were generally supportive of family presence during resuscitation[395,414] and felt that their function was not impaired by family presence.[394,395] However, across the studies, some apprehension about family presence was noted in health care professionals, and the need for family support personnel, training, and unit-based policies or protocols was identified.[396,399–401,410,412]

Prior Treatment Recommendations

New; no prior treatment recommendation

2023 Treatment Recommendations

We suggest that family members be provided with the option to be present during in-hospital and out-of-hospital adult resuscitation from cardiac arrest (weak recommendation; very low–certainty evidence), acknowledging that health care professionals are often not able to control this in out-of-hospital settings.

Policies or protocols about family presence during resuscitation should be developed to guide and support health care professional decision-making (good practice statement).

When family presence procedures are implemented, health care professionals should receive education about family presence during adult cardiac arrest resuscitation, including how to manage these stressful situations, family distress, and their own responses to these situations (good practice statement).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website.[386]

In making these recommendations, the EIT, BLS, and ALS Task Forces considered the following:

- Despite the variability in practices and outcomes of family presence during resuscitation, no evidence of harm for patients or families from family presence across the studies was found. Given the high desire for this choice and the potential for positive outcomes for family members, patients, and health care professionals, it was our opinion that family members should be given a choice to be present during resuscitation.
- Some family members may have cultural, religious, or other sociological factors that influence their attitudes and behaviors concerning family presence during adult resuscitation. Because none of the included studies investigated these factors, we have not made a formal recommendation about this; however, it will be important for resuscitation councils to adapt their recommendations accordingly.
- Attitudes and experiences of family presence during resuscitation may vary significantly by practice setting (out of hospital versus in hospital).
- Specific characteristics of cardiac arrests or patients (ie, younger versus older adult, precipitating illness or condition) were not reported in the included studies. The overall findings on patient, family, and health care professional outcomes were considered in the absence of this information.
- There were only 2 RCTs, both with methodological limitations,[387,388] comprising between 100 and 630 participants. We acknowledge the difficulty of an RCT in this setting. It would be unethical to stop a family member from being present or absent in these circumstances.
- The task force considered the reported negative psychological and family management experiences of health care professionals but thought implementation of education and unit-based policies and protocols would address many of these issues.
- Health care professional education and unit-based policies or protocols were not directly examined in any of the studies. However, 2 good practice statements were derived from the included studies considering the absence of any evidence of harm.
- No evidence was found on factors that may contribute to detrimental mental health outcomes after family-witnessed resuscitation for family members or health care professionals. Education or structured follow-up on possible long-term effects of witnessed resuscitation on these cohorts is needed.

Task Force Knowledge Gaps

- The impact of specific factors on patient, family, or health care professionals such as patient characteristics, precipitating events or illness resulting in cardiac arrest, family members as CPR bystanders, or the resuscitation setting
- The cultural, religious, or other sociological or health equity factors influencing attitudes and behaviors concerning family presence during adult resuscitation
- The impact of unit-based policies and protocols or family support personnel on patient, family, and health care professional outcomes with family presence during resuscitation
- Cost-effectiveness of resourcing the resuscitation setting to accommodate family presence and the impact of these resources on health care professionals
- Whether the effect of family presence during resuscitation varies with specific family members (eg, children, parents, partners)

Stepwise Approach to Skills Teaching in Resuscitation (SysRev)

Rationale for Review

The instructional approach for skills teaching is likely to affect later performance. The Peyton 4-step approach for skills teaching[418] has been implemented across standard

course formats of the European Resuscitation Council,[419] the United Kingdom Resuscitation Council, the Australian Resuscitation Council, and various national resuscitation councils in Europe. Walker and Peyton[418] defined the 4 steps as a sequence of (1) "demonstration" of the skill, at a normal pace, without commenting; (2) "deconstruction" of the skill, by demonstrating in slow motion, with detailed explanations for the learner with a special focus on critical steps; (3) "comprehension" by the learner, who explains each step while talking the teacher through the skill; and (4) "performance and practice" of the skill by the learner until performance is sufficient.[37] The superiority of the Peyton 4-step approach over other methods of skills teaching (eg, using <4 steps, substituting single steps by video,[420] no sequencing)[421] is unclear. A SysRev was therefore undertaken (PROSPERO registration CRD42023377398), and the full online CoSTR can be found on the ILCOR website.[422]

PICOST

- Population: Adults and children undertaking skills training related to resuscitation and first aid in any educational setting
- Intervention: Approaches to skills teaching that are not the Peyton 4-step approach. This includes approaches without distinct stages or modified Peyton 4-step approaches with >4 or <4 steps or with delivering ≥1 steps by alternative methods (eg, video).
- Comparators: The Peyton 4-step approach[418] for skills teaching because most studies used Peyton's 4 steps as the standard and compared alternative approaches against it
- Outcomes: Improved educational outcomes: Skill performance after the end of course, skill performance at end of course, participants' confidence to perform the skill on patients, and participants' preference of teaching method
  - Patient outcomes: Skills performed appropriately on a real patient after the course
  - Additional outcomes: Teachers' preference of teaching method and side effects of teaching
- Study designs:
  - Included studies: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies, published conference abstracts, and case series with n≥5)
  - Excluded studies: Unpublished results (eg, trial protocols), commentaries, editorials, and reviews
- Time frame: Publications from all years and all languages as long as there was an English abstract. The literature search was updated to November 25, 2022.

Consensus on Science

This SysRev included 16 studies, of which 13 were RCTs[423–435] and 3 were non-RCTs.[436–438] All studies showed a high degree of heterogeneity with respect to skills and populations taught, skill complexity, student-to-instructor ratios, and alternatives that were tested against the classic 4-step approach. Therefore, no meta-analyses could be performed.

No study was found for the clinical outcome of skills performed appropriately on a real patient after the course.

We identified 5 studies for the critical educational outcome of skill performance after ≥3 months (Table 29).[425,428,432,433,437] Four studies showed no difference,[425,432,433,437] and 1 found superior results using a 4-step approach.[428] However, in this study, the 4-step approach was 1 element of a bundle of "best practice" strategies.

For the important educational outcome of skill performance from end-of-course up to 3 months, (Table 30) we found 13 studies.[423,424,426,427,429-431,433-438] Eleven studies did not find differences for the primary outcomes,[423,424,427,429-431,433-437] but 2 studies found an advantage of 4 steps over 2 steps.[426,438]

We found 5 studies for the important educational outcome of participants' confidence to perform the skill on patients (Table 31).[423,425,429,436,437] None of these studies showed differences between the groups.

Three studies addressed the important educational outcome of participants' preference of teaching method (Table 32).[423,424,438] One study reported advantages for 4 steps compared with 2 steps[438]; in another study, no difference was found.[424] Another study provided comments made by students.[423]

Prior Treatment Recommendations

This PICOST was new in 2022; therefore, no prior treatment recommendation was available.

2023 Treatment Recommendation

We suggest that stepwise training should be the method of choice for skills training in resuscitation (weak recommendation, very low–certainty evidence).

Justification and Evidence-to-Decision Framework Highlights

The complete evidence-to-decision framework can be found on the ILCOR website.[422]

This topic aimed to provide evidence for the ongoing debate on the most appropriate training method for resuscitation skills because several resuscitation councils strongly focus on the Peyton 4-step approach in their instructor courses, but this is not universally done.[419]

In making the recommendation, the EIT Task Force considered the following:

- Insufficient evidence was found for resuscitation skills training showing superiority of the 4-step approach as proposed[418] compared with other approaches.
- The optimal stepwise training approach (including the number and type of steps) may depend on the type of skills taught and should be adapted to the nature of the skill taught.
- The solid foundation of stepwise training approaches in educational theory was acknowledged. We

Table 29. Summary of Evidence for Skill Performance After ≥3 Months

Study, y	Study type	Skill taught/primary outcome	Population taught/n	Type of alternative	Overall results	Certainty of evidence
Bomholt et al,[425] 2019	RCT	BLS-AED/BLS-AED scenario test at 3 mo	Laypeople/129	2-step skills teaching	Neutral	Low*
Herrmann-Werner et al,[428] 2013	RCT	Intravenous cannulation; insertion of nasogastric tube/performance scores at 6 mo	First-year medical students/94	"Traditional teaching" (2 steps)	4-step approach† superior	High
Münster et al,[432] 2016	RCT	BLS/chest compression quality‡ at 5–6 mo	First- and second-year medical students/134	3 steps (step 3 omitted) and 2 steps (Peyton steps 2 and 4)	Neutral	Low§
Nourkami-Tutdibi et al,[433] 2020	RCT	Neonatal life support/Megacode scenario score at 6 mo	Fourth- and fifth-year medical students/94	Modified 4-step approach‖	Neutral	Very low¶
Sopka et al,[437] 2012	Non-RCT	BLS (chest compression only)/chest compression quality at 6 mo	First-year medical students/220	Modified 4-step approach#	Neutral	Very low**

AED indicates automated external defibrillator; BLS, basic life support; and RCT, randomized controlled trial.
*Due to randomization and missing outcome data.
†"Best practice skills lab teaching," including "feedback," "manikin practice," and the 4-step approach.
‡Chest compression rate, depth, and chest compression fraction.
§Due to randomization.
‖Step 3 including additional functional verbalization by the student.
¶Due to high dropout rate.
#Podcast for steps 1 and 2.
**Due to "confounding" and "deviations from the intended intervention."

do not support the use of nonstepwise training approaches.
- Two studies showed advantages of 4 steps compared with 2 steps. However, such 2-step approaches appear to have little educational structure (show it, do it).
- Skills training using a 4-step approach, or modifications of it, should be limited to skills of low to moderate complexity. Really complex skills should be broken up into >1 training session.[439]
- Most of the studies were conducted with health care students of various professions. We cannot translate these results to other learner populations (eg, children).
- None of the studies controlled for the teaching quality of individual instructors.
- There is a risk that instructors may move away from all types of stepwise skills teaching. Instructor training needs to emphasize the importance of such stepwise skills training approaches.

Task Force Knowledge Gaps

- The impact of the quality of the individual teacher performance
- A need for an Utstein-like uniform reporting of educational outcomes in resuscitation science to allow comparative summaries of such studies
- The learning needs of different participant groups and how stepwise training should be adapted to their needs (eg, children or elderly)
- The effect of step sequence and number of steps for training of various skills in different learner populations
- The effect of different approaches to skills teaching on participants' performance on real patients

Disparities in Layperson Resuscitation Education (ScopRev)

Rationale for Review

Layperson training in CPR is crucial, as well as increasing public awareness of cardiac arrest measures to enhance layperson involvement in lifesaving attempts.[440] Unfortunately, not every individual has equal access to resuscitation education programs, and many underresourced populations lack access to CPR education. The reasons for these inequities have yet to be fully described.[441]

Identifying disparities in access to resuscitation education will help to target training and potentially increase public layperson involvement in OHCA. In this ScopRev, we aimed to identify and describe factors that either promote or hinder laypeople from attending resuscitation education courses. The full online CoSTR can be found on the ILCOR website.[442]

Population, Exposure, Comparator, Outcome, Study Designs, and Time Frame

- Population: Laypeople (non–health care professionals)
- Exposure: Presence of any factors that would possibly enhance or hinder the opportunity for laypeople to undertake resuscitation education
- Comparators: Absence of the specific factor
- Outcomes: Likelihood of undertaking resuscitation education, including adult and pediatric BLS courses, and the neonatal resuscitation program
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. Unpublished studies (eg, conference abstracts, trial protocols), letters, editorials,

Table 30. Summary of Evidence for Skill Performance at End of Course

Study, y	Study type	Skill taught/primary outcome	Population taught/n	Type of alternative	Overall results	Certainty of evidence
Archer et al,[423] 2015	RCT	Manual defibrillation/composite score for defibrillation skills at end of course and at 2 mo	First-year medical students/294	Traditional 2-step and 5-step approaches	Neutral*	Very low†
Bjornshave et al,[424] 2018	RCT	Single-rescuer BLS plus AED/ pass rate at end of course	Laypeople/142	"Traditional" 2-step approach	Neutral	High
Frangez et al,[426] 2017	RCT	BLS (without AED)/BLS scenario test‡ at end of course	First-year medical students/266	"Conventional" 2-step approach	4-step approach superior§	High
Greif et al,[427] 2010	RCT	Needle cricothyroidotomy/time needed to successful ventilation at end of course	Fourth-year medical students/128	3 alternatives: traditional 2 steps, step 2 omitted, step 3 omitted	Neutral (for all 4 approaches)	Low‖
Jenko et al,[429] 2012	RCT	Chest compressions/BLS scenario test‡ at end of course	First-year medical students/126	2-step approach	Neutral	Concerns; low¶
Krautter et al,[430] 2011	RCT	Inserting a nasogastric tube/ performing steps of the procedure at end of course	Second- and third-year medical students/34	2-step approach	Neutral#	High
Lapucci et al,[431] 2018	RCT	Chest compressions and ventilation	Nursing students/60	2-step approach	Neutral	Low**
Nourkami-Tutdibi et al,[433] 2020	RCT	Neonatal life support/Megacode scenario at 4 d after intervention	Advanced medical students/94	Modified 4 steps (step 3)	Neutral	Low‡‡
Orde et al,[434] 2010	RCT	Laryngeal mask insertion/ proportion of participants achieving ventilation <30 s	Critical care nurses, ICU nursing students, final-year medical students/120	2-step approach	Neutral	Low§§
Schauwinhold et al,[436] 2022	Non-RCT	BLS/chest compression rate and depth at end of course	First-year medical, dentistry, and physiotherapy students/346	3 steps with TSP	Neutral (noninferiority of the TSP group)	Very low‖‖
Schwerdtfeger et al,[435] 2014	RCT	Advanced trauma life support/ median OSCE score at end of course	Advanced medical students/256	Modified 4-step approach (steps 1 and 2 by video)	Neutral¶¶	Low##
Sopka et al,[437] 2012	Non-RCT	BLS (chest compression only)/ chest compression quality at end of course	First-year medical students/220	Modified 4-step approach***	Neutral	Low†††
Zamani et al,[438] 2020	Non-RCT	TI/TI score at end of semester	Advanced medical students/124	2 steps	4-step approach superior	Very low‖‖

AED indicates automated external defibrillator; BLS, basic life support; ICU, intensive care unit; OSCE, objective structured clinical examination; RCT, randomized controlled trial; TI, tracheal intubation; and TSP, tele-instructor–supported peer feedback.

*For direct statistical comparison between 2 steps and 4 steps, the 2-step approach was superior.

†Due to high dropout rate.

‡Scenario steps: call for help, open airway, hand position, and chest compressions correct.

§The study analyzed students trained with the 2000 and 2005 European Resuscitation Council Guidelines. The authors found more pronounced effects of the 4-step approach for 2000 guidelines (compared with 2005, perceived as simpler).

‖Due to deviations from the intended intervention and measurement of the outcome (intervention included elements of mastery learning).

¶Due to randomization.

#For primary outcome; for 3 secondary outcome, advantages for the 4-step approach (time to complete insertion, professionalism, and communication).

**Due to selection of reported results.

††Step 3 including additional functional verbalization by the student.

‡‡Due to measurement of the outcome.

§§Due to randomization.

‖‖Due to confounding, selection, and measurement of outcomes.

¶¶For a global score, the modified 4-step approach was superior to the original 4-step approach.

##Due to missing outcome data and measurement of outcomes.

***Podcast for steps 1 and 2.

†††Due to confounding, deviations from intended intervention.

comments, and case reports were excluded. All relevant publications in any language were included as long as there was an English abstract.

- Time frame: All years and all languages were included as long as there was an English abstract. The literature search was updated to August 31, 2022.

Summary of Evidence

This review included 22 studies[443–464]: 19 cross-sectional studies[443,444,446–453,455–457,459–464] and 3 retrospective cohort studies.[445,454,458] A complete overview of study characteristics and key findings is presented in Appendix A. All studies were related to resuscitation training for adults,

Table 31. Summary of Evidence for Participants' Confidence to Perform the Skill on Patients

Study, y	Study type	Skill taught/outcome	Population taught/n	Type of alternative	Overall results	Certainty of evidence
Archer et al,[423] 2015	RCT	Manual defibrillation/confidence to perform manual defibrillation on a manikin and on a patient	First-year medical students/294	Traditional 2-step and 5-step approaches	Neutral	Very low*
Bomholt et al,[425] 2019	RCT	BLS-AED/self-confidence to perform BLS/AED on patient	Laypeople/129	2-step skills teaching	Neutral	Low†
Jenko et al,[429] 2012	RCT	Chest compressions/self-evaluated BLS competence	First-year medical students/126	2-step approach	Neutral‡	Low§
Schauwinhold et al,[436] 2022	Non-RCT	BLS/confidence in CPR performance, handling emergency situation, and real-life situation	First-year medical, dentistry, and physiotherapy students/346	3 steps with TSP	Neutral (noninferiority of the TSP group)	Very low‖
Sopka et al,[437] 2012	Non-RCT	BLS (chest compression only)/self-confidence for knowledge of the algorithm and chest compression performance	First-year medical students/220	Modified 4-step approach¶	Neutral	Low#

AED indicates automated external defibrillator; BLS, basic life support; CPR, cardiopulmonary resuscitation; RCT, randomized controlled trial; and TSP, tele-instructor–supported peer feedback.

*Due to high dropout rate.

†Due to randomization and missing outcome data.

‡Both groups overrated their performance ≈50% in relation to objective performance.

§Due to randomization.

‖Due to confounding, selection, and measurement of outcomes.

¶Podcast for steps 1 and 2.

#Due to confounding, deviations from intended intervention.

published between 1987 and 2022. A thematic assessment of enablers or barriers to attending CPR education resulted in 3 main themes: (1) personal, (2) socioeconomic and higher education, and (3) geographic factors. Identified enablers and barriers within these thematic areas and a summary of the studies finding higher, lower, or unchanged resuscitation training attendance associated with each variable are summarized in Table 33.

Task Force Insights

Enablers and barriers for layperson resuscitation education were identified that might inform targeted training initiatives for laypeople with a reduced likelihood of undertaking resuscitation education.

Older age groups are often out of reach of existing conventional CPR education strategies. Targeted approaches include increasing availability by providing convenient training locations, generating more publicity and awareness of resuscitation, and promoting group or couples' participation.[465] Targeted education should also be applied to laypeople with small children, and age-appropriate CPR training can be taught to school-aged children.[466–468]

Higher educational and income levels and socioeconomic status were associated with more resuscitation training. Specific targeted training for populations with lower educational standing or lower incomes may be beneficial. Mandatory CPR training (eg, before acquiring a driver's license) might increase layperson CPR willingness, but the downstream effects warrant further investigation.[458,459,469] Legal requirements for school-based resuscitation education increased resuscitation training among students and adults in such regions in 1 study.[444]

People of color were less likely to receive proper bystander resuscitation from laypeople or medical

Table 32. Important Educational Outcome: Participants' Preference of Teaching Method

Study, y	Study type	Skill taught	Population taught/n	Type of alternative	Overall results	Certainty of evidence
Archer et al,[423] 2015	RCT	Manual defibrillation	First-year medical students/294	Traditional 2-step and 5-step approaches	Students in the 4-step group wanted more practice. Students found "Demonstration with explanation" and "Practice session with educator feedback" the most useful parts (in 29% and 25%, respectively)	Very low*
Bjornshave et al,[424] 2018	RCT	Single rescuer BLS plus AED	Laypeople/142	"Traditional" 2-step approach	No difference of students' satisfaction	Very low
Zamani et al,[438] 2020	Non-RCT	TI/TI score at end of semester	Advanced medical students/124	2 steps	Higher satisfaction score in 4-step group (19% difference; $P<0.001$)	Very low†

AED indicates automated external defibrillator; BLS, basic life support; RCT, randomized controlled trial; and TI, tracheal intubation.

*Due to high dropout rate.

†Due to confounding, selection, and measurement of outcomes.

Table 33. Factors Associated With Resuscitation Education Among Laypeople

	Higher attendance	Lower attendance	No difference in attendance
Personal factors			
Age		Older age[444–448,450,451,453,455–460,462,463]	No age difference[461,464]
Sex	In men[448,449,458] In women[446,456,463]		No difference or inconclusive between sexes[444,447,450–453,457,461,462,464]
Race		Lower training rates Hispanic/Latino[445,450,462] or Black individuals[445]	No difference between White and non-White individuals[444]
Language		Poor proficiency in English[454,461]	
Family	Married or living as married[456]	Having small children at home[458]	
Experience	Witnessing a collapsed person[456,459] Awareness of AED in public places[459]		
Immigration	Longer stay in immigrated country[461]		
Socioeconomic status and higher education factors			
Education	With higher level of education[443,444,446,449–452,455,461–464]		No significant association[445]
Income		With lower income[443,445,450,464]	No significant difference[462]
Socioeconomic status		With lower socioeconomic status[453,456,457]	
Occupation	Employees,[447,449,452,456] students,[447,449,456] skilled workers[459]		
Driver's license	Having driver's license[459]		
Legislation	Laws requiring school-based training[444]		
Geographic factors			
Born	Native-born in the country[447,451]	Southern European–born individuals, Southeast Asian–born individuals in Australia[454]	No significant difference[446]
Habitancy	Living in rural area[447,458]	Living in rural area[445]	No significant difference[446,464]

AED indicates automated external defibrillator.

staff.[470–473] Deficiency of mutual trust in the community and inadequate language proficiency have been speculated as being barriers.[474–476] An interventional study aiming to teach refugees coming from 19 countries reported that English serving as a universal language was insufficient, and conducting BLS courses in the participants' native language was optimal.[477] Multifaceted system-wide interventions should be initiated to reduce structural biases or discrimination and to increase resuscitation training for all populations living.

The influence of geographic factors and sex on resuscitation education is unclear and needs to be further investigated. The majority of the studies came from highly developed countries, and evidence from low-resource areas or remote areas is required to address this question.

Our search did not identify any studies assessing disparities in pediatric or neonatal resuscitation educational programs for laypeople or in CPR education programs for children. No studies looked at disparities in CPR training based on mental or physical disability, yet it is important for the disabled to have the opportunity to receive resuscitation training.[478]

Treatment Recommendations

There was no prior treatment recommendation addressing disparities in layperson resuscitation education. This ScopRev has not identified sufficient evidence to prompt a SysRev or a meta-analysis. However, on the basis of expert opinion from the ILCOR EIT Task Force, significant gaps in knowledge and open research questions were highlighted, specifically to include underresourced populations.

Task Force Knowledge Gaps

- How to design or target resuscitation educational programs to best serve underrepresented or historically excluded populations
- The influence of geographic factors (eg, urban or rural areas, low-resource settings, remote areas), sex of laypeople, or the impact of laws requiring CPR training on the attendance of resuscitation education courses
- The extent of disparities in layperson resuscitation education in populations with special needs such as disabled people, pregnant women, schoolchildren, or kindergarten-aged children; pediatric or neonatal resuscitation
- The influence of these barriers or enablers on the clinical outcome of OHCA

EIT Topics Reviewed by EvUps

Topics reviewed by EvUps are summarized in Table 34, with the PICO, existing treatment recommendation,

Table 34. EIT Topics Reviewed by EvUps

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Patient outcomes from team member(s) attending a CPR course (EIT 6106)	2021	We recommend the provision of accredited adult ACLS/ALS training for health care providers who provide ALS care for adults (strong recommendation, very low–certainty evidence). We recommend the provision of accredited NRT courses for health care professionals who provide ALS care for newborns and babies (strong recommendation, very low–certainty evidence). We recommend the provision of Helping Babies Breathe support training for health care providers who provide ALS care for newborns and babies (strong recommendation, very low–certainty evidence).	0	1	One new article was identified relevant to this PICO. The results of these studies support and strengthen the current ILCOR CoSTR recommendation. Given that this is an observational study and no new RCT is available, the identified study would not increase the existing very low certainty of evidence and change the current recommendation.	No. This EvUp does not meet the criteria to trigger a new SysRev.
CACs (EIT 6301)	2021	We suggest that adult patients with nontraumatic OHCA be cared for in CACs rather than in non-CACs (weak recommendation, very low–certainty evidence). We cannot make a recommendation for or against regional triage by primary EMS transport of patients with OHCA to a CAC by primary EMS transport (bypass protocols) or secondary interfacility transfer to a CAC. The current evidence is inconclusive and confidence in the effect estimates is currently too low to support an EIT and ALS Task Force recommendation. For patients with IHCA, we found no evidence to support an EIT and ALS Task Force recommendation. For the subgroup of patients with shockable or nonshockable initial cardiac rhythm, the current evidence is inconclusive, and the confidence in the effect estimates is currently too low to support an EIT and ALS Task Force recommendation.	0 RCTs 4 SysRevs	4	The SysRevs reported improved outcomes for patients with OHCA who were transported to a CAC. One observational study reported improved survival and neurological outcome for patients who were transferred to a CAC; another found that patients transported to CAC in mixed urban/rural area may have improved survivwal compared with those in a metropolitan area. Two studies comparing high- and low-volume hospitals reported conflicting results, with one reporting better outcomes from high-volume hospitals and one finding no difference in outcomes.	Yes. The new evidence will not change the 2020 treatment recommendation. EIT and ALS Task Forces should consider updating the SysRev after the publication of an RCT in 2023 (ARREST; ClinicalTrials.gov identifier, NCT03872960).
Technology to summon providers (EIT 6302)	2020	We recommend that citizen/individuals who are in close proximity to a suspected OHCA event and willing to be engaged/notified by a smartphone app with an MPS or TM alert system should be notified (strong recommendation, very low–certainty evidence).	3 SysRevs but 0 RCTs	6	The 3 SysRevs favored first-responder systems; the RCT reported about alarming systems of laypeople by dispatchers. The summary of these studies supports the current ILCOR CoSTR recommendation. Given that no RCT data are available, the identified studies would not change the existing recommendation on the basis of very low certainty of evidence.	No. This EvUp does not meet the criteria to trigger a new SysRev. However, the focus on alarming laypeople as first responders might trigger a separate PICOST reviewing the evidence of such systems.
Prehospital TOR rules (EIT 6303)	2021	We conditionally recommend the use of TOR rules to assist clinicians in deciding whether to discontinue resuscitation efforts out of hospital or to transport to hospital with ongoing CPR (conditional recommendation, very low–certainty evidence).	0	2	One study applied a medical TOR rule and a surgical TOR rule for pediatric patients (pTOR) and correctly found 322/323 patients as not eligible for the medical pTOR. The traumatic pTOR rule misclassified 4/54 patients with ROSC. This pTOR rule was unable to correctly classify all patients as not eligible for TOR.	Yes. Because pediatric cardiac arrests may be considered a specific situation with many life-years at risk and only 1 historical cohort study looked at pTOR rules without showing convincing results, a new SysRev may find that TOR rules cannot be recommended for pediatric OHCAs. Accordingly, updating the SysRev is recommended.

(*Continued*)

Table 34. Continued

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
CPR feedback devices during training (EIT 6404)	2020	We suggest the use of feedback devices that provide directive feedback on compression rate, depth, release, and hand position during CPR training (weak recommendation, low-certainty evidence). If feedback devices are not available, we suggest the use of tonal guidance (examples include music or metronome) during training to improve compression rate only (weak recommendation, low-certainty evidence).	7	3	All studies examined the effect of corrective feedback on objectively measured CPR quality as a primary outcome measure. The 5 RCTs demonstrate significant benefits of the CPR feedback device used during resuscitation courses, although the study populations were mostly novice health care professionals and laypeople. All studies focused on initial training rather than renewal course.	Yes. The studies are consistent with the previous reviews and continue to support the use of CPR feedback devices during resuscitation training. Given the fairly large number of new studies, a formal SysRev with meta-analysis is recommended.
CPR self-instruction vs instructor-guided training (EIT 6406)	2020	We recommend instructor-led training (with manikin practice with feedback device) or the use of self-directed training with video kits (instructional video and manikin practice with feedback device) for the acquisition of CPR theory and skills in lay-adults and high school–aged (>10 y) children (strong recommendation, moderate quality of evidence). We recommend instructor-led training (with AED scenario and practice) or the use of self-directed video kits (instructional video with AED scenario) for the acquisition of AED theory and skills in lay-adults and high school–aged (>10 y) children (strong recommendation, low quality of evidence). We suggest BLS video education (without manikin practice) be used when instructor-led training or self-directed training with video kits (instructional video plus manikin with feedback device) is not accessible or when quantity over quality of BLS training is needed in adults and children (weak recommendation, weak quality of evidence). There was insufficient evidence to make a recommendation for gaming as a CPR or AED training method. There was insufficient evidence to suggest a treatment effect on bystander CPR rates or patient outcomes.	1 narrative review	One 6-mo follow-up study of an RCT	The narrative review suggests introducing self-directed learning, interactive digital, and abbreviated formats in communities and classroom teaching because CPR performance seems equivalent to traditional courses. The follow-up study reported still high willingness to perform CPR after 6 mo.	No. The results of both of these studies support the current ILCOR CoSTR recommendation. Therefore, on the basis of the limited additional results, no new review was suggested.
In situ simulation-based resuscitation training for health care professionals (EIT 6407)	2021	This EvUp does not enable a treatment recommendation to be made.	0	2	An in situ program for ECMO did not report significant changes in a before-and-after study. Another in situ interdisciplinary intraoperative code blue simulation training session on technical skills, nontechnical skills, and self-reported comfort reported significant improvements.	No. On the basis of the limited additional evidence of this search, with no RCTs identified, this EvUp does not meet the criteria to trigger a formal systematic or ScopRev.

ACLS indicates advanced cardiovascular life support; AED, automated external defibrillator; ALS, Advanced Life Support; app, application; ARREST, A Randomized Trial of Expedited Transfer to a Cardiac Arrest Centre for Non-ST Elevation Out-of-Hospital Cardiac Arrest; BLS, basic life support; CAC, cardiac arrest center; CoSTR, International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations; CPR, cardiopulmonary resuscitation; ECMO, extracorporeal membrane oxygenation; EIT, Education, Implementation, and Teams; EMS, emergency medical services; EvUp, evidence update; IHCA, in-hospital cardiac arrest; ILCOR, International Liaison Committee on Resuscitation; MPS, mobile positioning system; NRT, Neonatal Resuscitation Training; OHCA, out-of-hospital cardiac arrest; PICO, population, intervention, comparator, outcome; PICOST, population, intervention, comparator, outcome, study design, time frame; pTOR, pediatric termination of resuscitation; ROSC, return of spontaneous circulation; RCT, randomized controlled trial; ScopRev, scoping review; SysRev, systematic review; TM, text message; and TOR, termination of resuscitation.

number of studies identified, key findings, and whether a SysRev was deemed worthwhile provided. Complete EvUps can be found in Appendix B.

FIRST AID

Pulse Oximetry Use in the First Aid Setting (ScopRev)

Rationale for Review

Pulse oximetry has been used for monitoring of hospitalized patients at risk of hypoxemia and, more recently, for home use during the COVID-19 pandemic. The First Aid Task Force considered it timely to undertake a ScopRev to identify evidence relating to the use of pulse oximetry as a component of first aid assessment of acute symptoms associated with illness or injury. The full online CoSTR can be found on the ILCOR website.[479]

PICOST

- Population: Adults and children in the out-of-hospital or home setting with an acute illness or injury
- Intervention: Use of pulse oximetry in addition to standard first aid assessment
- Comparators: Standard first aid assessment without the use of pulse oximetry
- Outcomes: Any clinical outcome
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies), gray literature, social media and non–peer-reviewed studies, unpublished studies, conference abstracts, and trial protocols were eligible for inclusion.
- Time frame: All years up to November 16, 2022

Summary of Evidence

Our search identified 4204 unique articles, of which 16 underwent full-text review. All were ultimately excluded because they enrolled patients in home monitoring programs for a known, diagnosed infection or disease.

Although the search strategy for this ScopRev was not designed to capture studies evaluating the accuracy of pulse oximetry based on skin pigmentation, some such studies were identified. In 1 study, there was a greater discrepancy between oxygen saturation as measured by pulse oximetry and that measured by blood gas (with pulse oximetry providing the higher number in general) in individuals identified as Black, Asian, or mixed ethnicity compared with those identified as White (Black, 1.8% [95% CI, 0.2–3.4], P=0.04; Asian, 1.9% [95% CI, 0.6–3.2], P=0.005; mixed ethnicity, 3.2% [95% CI, −0.1 to 6.6], P=0.06).[480] In another study, Black patients had nearly 3 times the frequency of occult hypoxemia (hypoxemia not detected by pulse oximetry) as White patients.[481]

Task Force Insights

The evidence identified in this ScopRev is not directly relevant to the first aid use of a pulse oximetry as a means of assessment for acute symptoms from illness or injury. Although there were reports of the early detection of asymptomatic hypoxemia in the out-of-hospital setting with pulse oximeters, we also identified concerns about device limitations, accuracy, reliability, and disparities in oximetry accuracy based on skin pigmentation. Although this search strategy was not designed to capture studies comparing the accuracy of pulse oximetry based on factors such as skin pigmentation, the First Aid Task Force is aware of multiple other studies evaluating this issue in addition to the ones identified. Findings generally support a small but statistically significant increase in occult hypoxemia in patients with darker skin.[482–486]

The First Aid Task Force expressed concerns about storage of oximeters in first aid kits, issues with readings due to movement and vibration, and outdoor use in settings with high humidity or extremes of temperature. Additional concern was expressed about the accuracy of oximeters sold as non–medical-use devices and used by the public to assist with self-identification of hypoxemia without training in their use, limitations, and interpretation of findings. Last, most home pulse oximetry monitors do not show the waveform, leading to challenges with interpreting the results.

Although there is not sufficient evidence to support a recommendation for (or against) the use of a pulse oximeter by first aid providers, we recognize that pulse oximeters are readily available for purchase, may be found in some first aid kits, and may be in use by some first aid providers. There is inadequate evidence to pursue a SysRev at this time.

Good Practice Statements

First aid providers who use pulse oximeters for the assessment of acute illness or injuries should be proficient in their use and understand their limitations, including equipment factors, environmental considerations, and patient-specific factors that may produce inaccurate and unreliable readings (good practice statement).

The use of a pulse oximeter for first aid assessment should not supersede or replace physical assessment (good practice statement).

Use of Supplemental Oxygen in First Aid (ScopRev)

Rationale for Review

Although supplemental oxygen has been advocated as a beneficial treatment in several conditions, recent work has found evidence of harm with excessive oxygen administration in some patient populations such as those with suspected myocardial infarction.[487] Because supplemental oxygen may be administered in these conditions

and others in the first aid setting, an understanding of the potential risks and benefits of supplemental oxygen administration is critical to first aid providers. The full online CoSTR can be found on the ILCOR website.[488]

PICOST

- Population: Adults and children with signs or symptoms of shortness of breath, difficulty breathing, or hypoxia outside of a hospital
- Intervention: Administration of oxygen by a first aid provider
- Comparators: No administration of oxygen
- Outcomes: Functional outcome at discharge, 30 days, 60 days, 180 days, and 1 year; survival only at discharge, 30 days, 60 days, 180 days, and 1 year; length of hospital stay, resolution of symptoms or signs, patient comfort, and therapeutic end points (eg, oxygenation, ventilation)
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies), case series and reports, gray literature, social media, non–peer-reviewed studies, unpublished studies, conference abstracts, and trial protocols were eligible for inclusion. Only English language articles were included.
- Time frame: January 1, 2000, to July 1, 2022

Summary of Evidence

Our search identified 2256 unique articles, of which 16 underwent full-text review. No articles directly addressed the review question.

One cluster randomized trial compared EMS use of high-flow oxygen (defined as 8–10 L/min oxygen) with the use of titrated oxygen (titrated to an oxygen saturation of 88%–92%) for patients with acute chronic obstructive pulmonary disease (COPD) exacerbations and found a lower mortality rate in patients treated with titrated oxygen (relative risk, 0.42 [95% CI, 0.20–0.89]).[489]

Task Force Insights

This ScopRev did not identify any direct evidence for or against the routine administration of oxygen in adults or children exhibiting signs or symptoms of shortness of breath, difficulty breathing, or hypoxia outside of a hospital.

The current review has yielded evidence that oxygen therapy at an untitrated rate of 8 to 10 L/min is harmful in patients with acute exacerbations of COPD being treated by EMS, and oxygen needs to be titrated to the patient's oxygen saturation in this setting. This has implications for first aid providers given that the 2015 CoSTR did not identify harms associated with the use of oxygen in patients displaying symptoms of shortness of breath.[490]

We acknowledge that recognition of acute exacerbations of COPD and the use of pulse oximetry may be beyond the skill set of many first aid providers. However, some organizations teaching advanced first aid or first aid oxygen courses may include teaching on the use of pulse oximetry, so there may be circumstances where the administration of supplemental oxygen by first aid providers is common practice.

This review specifically excluded the use of supplemental oxygen in acute coronary syndrome,[487] suspected stroke,[491] drowning,[3] and after ROSC following cardiac arrest[57] because these indications have been covered in recent reviews.

Given the potential for harm with untitrated oxygen, we suggest a good practice statement that supplements the 2015 CoSTR and includes the aforementioned considerations for patients with COPD. There is inadequate evidence to pursue a SysRev on this topic at this time.

Prior Treatment Recommendations (2015)

No recommendation was made; the confidence in the effect estimate is so low that the task force thinks a recommendation to change current practice is too speculative.

2023 Good Practice Statement

If first aid providers, trained to use oxygen, are administering supplemental oxygen to a person with known COPD, they should titrate the supplemental oxygen to maintain an oxygen saturation by pulse oximetry between 88% and 92% (good practice statement).

Recognition of Anaphylaxis (ScopRev)

Rationale for Review

Anaphylaxis is a time-sensitive condition for which early recognition and treatment with epinephrine are critical. It is unknown whether the presence or absence of any specific symptoms can assist first aid providers in appropriately identifying individuals with anaphylaxis. The full online CoSTR can be found on the ILCOR website.[492]

PICOST

- Population: Adults and children experiencing anaphylaxis
- Intervention: The description of any specific symptoms to the first aid provider
- Comparators: Absence of any specific description
- Outcomes: Recognition of anaphylaxis
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies), case series or reports, gray literature, social media publications, non–peer-reviewed studies, unpublished studies, conference abstracts and trial protocols were eligible for inclusion. All relevant publications in any language were included as long as there was an English abstract.
- Time frame: All years to September 19, 2022

Summary of Evidence

Our search identified 949 unique articles, of which 18 underwent full-text review. No articles directly addressed

the review question. Several of these studies reported an increase in knowledge of how to recognize anaphylaxis after educational interventions, viewing videos, health application (app) use, and coaching.[493–502]

Other identified studies examined the effectiveness of action plans[503,504] and educational interventions to improve recognition of anaphylaxis[505–508] and the relationship between education on anaphylaxis recognition and the use of epinephrine.[509]

Task Force Insights

Although none of the studies identified specific signs or symptoms that may be used by first aid providers in the identification of anaphylaxis, several surveys reported improvement in the ability to recognize anaphylaxis immediately after individual or community-level educational engagements.

New initiatives to improve recognition and management of anaphylaxis should be studied to evaluate their effectiveness and efficiency.

Previous literature has identified different factors associated with underuse of epinephrine in anaphylaxis.[510,511] Recognition of anaphylaxis is one of the identified factors that can reduce the delay in the administration of epinephrine when it is available, although evidence for this is limited. Recognition of anaphylaxis is not the only barrier to the first aid use of epinephrine autoinjectors. The high cost of epinephrine autoinjectors, lack of availability in some settings, lack of epinephrine use even when it is available, incorrect administration technique, and fear of harm with administration are also barriers.

There is inadequate evidence to pursue a SysRev of this topic at this time.

Prior Treatment Recommendation (2010), Unchanged

First aid providers should not be expected to recognize the signs and symptoms of anaphylaxis without repeated episodes of training and encounters with individuals with anaphylaxis.[512]

Potential Harms From Bronchodilator Administration (ScopRev)

Rationale for Review

People with asthma exacerbations benefit from administration of bronchodilators. However, it is unknown whether first aid providers can appropriately identify asthma exacerbations, and it is unknown whether bronchodilators could result in harm if administered to individuals with undifferentiated respiratory symptoms. The full online CoSTR can be found on the ILCOR website.[513]

PICOST

- Population: Adults and children in any setting with acute undifferentiated respiratory problems
- Intervention: Administration of any type of inhaled bronchodilator (eg, β-agonists, anticholinergics)
- Comparators: No administration of an inhaled bronchodilator
- Outcomes: Survival, dysrhythmia, cardiac ischemia, hypokalemia, need for emergency department treatment, need for hospitalization, or time to treatment
- Study designs: RCTs and nonrandomized studies (non-RCTs, interrupted time series, controlled before-and-after studies, cohort studies) and case series were eligible for inclusion. Only English language studies were included.
- Time frame: All years to November 2, 2022

Summary of Evidence

Our search identified 403 unique articles, of which 15 underwent full-text review. Thirteen articles were identified that reported adverse effects of short-acting inhaled bronchodilators that could be available to first aid providers caring for patients with reactive airway disease; however, none directly addressed the PICOST. Examples of identified adverse effects were tachycardia, arrhythmias, tremor, dizziness, and a decrease in serum potassium concentrations. Bronchodilators included albuterol (salbutamol) through a nebulizer, albuterol (salbutamol) through a metered dose inhaler, fenoterol through a metered dose inhaler, ipratropium through a nebulizer, and metaproterenol through a nebulizer.

Tachycardia was noted with albuterol; however, the increase in heart rate was less when albuterol was delivered through metered dose inhaler compared with delivery by nebulizer (MD, −6.47 bpm [95% CI, −11.69 to −1.25]; *P*=0.02).[514] Other studies noted palpitations (salbutamol)[515] and premature ventricular contractions (fenoterol and albuterol)[516] after the use of inhaled bronchodilators.

Multiple studies[516–519] documented a decrease in serum potassium concentration after the use of short-acting β-agonists, although these were typically mild (mean decrease, 0.54 mmol/L in 1 study and 0.52 mmol/L in another)[517,520] and of uncertain clinical significance.

Case reports[521–524] describe multiple side effects in patients exposed to short-acting bronchodilators. A case of unilateral mydriasis developed after nebulized ipratropium came into contact with an eye, resulting in the person receiving a CT scan of the brain to evaluate for intracranial abnormalities.[521] Severe bronchospasm occurred after exposure to an albuterol inhaler and nebulizer treatment.[522] Last, 1 patient developed takotsubo cardiomyopathy that was associated with repetitive use of an albuterol inhaler.[524]

Task Force Insights

Most studies included patients with reactive airway diseases.

An increase in heart rate (eg, by an average of 13 bpm in 1 study of metaproterenol) could cause myocardial ischemia in a patient with cardiac disease or could

Table 35. First Aid Topics Reviewed by EvUps

Topic/PICO	Year last updated	Existing treatment recommendation	RCTs since last review, n	Observational studies since last review, n	Key findings	Sufficient data to warrant SysRev?
Cervical spinal motion restriction (FA7334)	2015	We suggest against the use of cervical collars by first aid providers (weak recommendation, very low–quality evidence).	3	5	Given limited additional information on spinal motion restriction identified in this EvUp, the task force did not feel that there was sufficient information to pursue a systematic review or the reconsideration of current treatment recommendations.	No
Hemostatic agents for life-threatening external bleeding (FA7334)	2020	We suggest that first aid providers use a hemostatic dressing with direct pressure as opposed to direct pressure alone for severe, life-threatening external bleeding (weak recommendation, very low-certainty of evidence). For the treatment of severe, life-threatening external bleeding by first aid providers, due to very limited data and very low confidence in effect estimates, we are unable to recommend the use of any one specific type of hemostatic dressing compared with another.	None	None	Most new articles are on postsurgery bleeding or malignant ulcers.	No

EvUp indicates evidence update; PICO, population, intervention, comparator, outcome; and RCT, randomized controlled trial.

exacerbate tachyarrhythmias such as supraventricular tachycardia.[525] Inhaled short-acting β-agonists are associated with a decrease in plasma potassium values, typically by <1 mmol/L (eg, a mean decrease of 0.54 mmol/L in 1 study and 0.52 mmol/L in another).[517,520] Whether these adverse effects outweigh the potential benefit of bronchodilators is unknown.

There is inadequate evidence to undertake a SysRev on harm of bronchodilators and therefore inadequate evidence to amend the 2015 CoSTR on the use of bronchodilators in individuals with asthma.

Prior Treatment Recommendation (2015), Unchanged

When an individual with asthma is experiencing difficulty breathing, we suggest that trained first aid providers assist the individual with administration of a bronchodilator (weak recommendation, very low–certainty evidence).[526]

First Aid Topics Reviewed by EvUps

Topics reviewed by EvUps are summarized in Table 35, which provides the PICO, existing treatment recommendation, number of studies identified, key findings, and whether a SysRev was deemed worthwhile. Complete EvUps can be found in Appendix B.

ARTICLE INFORMATION

The American Heart Association, the European Resuscitation Council, and the International Liaison Committee on Resuscitation make every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

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Disclosures

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(*Continued*)

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Chih-Wei Yang	National Taiwan University Hospital (Taiwan)	None	None	None	None	None	None	None
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This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $5000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $5000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

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Patricia Conaghan	The University of Manchester (United Kingdom)	None	None	None	None	None	European Resuscitation Council (uncompensated)*; Resuscitation Council UK (uncompensated)*	None
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Marilyn B. Escobedo	University of Oklahoma Medical School	None	None	None	None	None	None	None
Steven C. Faddy	New South Wales Ambulance, Sydney (Australia)	None	None	None	None	None	None	None
Christian Hassager	Rigshospitalet (Denmark)	Novo Nordisk Foundation (I have received a research grant for a trial that evaluates the effect of steroid treatment immediately after resuscitation of out of hospital cardiac arrest and one regarding in-hospital treatment of resuscitated patients with out-of-hospital cardiac arrest. These grants are used for the expenses in these trials; this has no impact on my own salary.)†	None	None	None	None	None	None
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(*Continued*)

Reviewer Disclosures Continued

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Carsten Lott	Johannes Gutenberg University Medical Center (Germany)	None	None	None	None	None	None	None
Colm P. F. O'Donnell	National Maternity Hospital (Ireland)	None	None	None	None	None	None	None
Peter Paal	St. John of God Hospital, Paracelsus Medical University (Austria)	None	None	None	None	None	None	None
Sarah M. Perman	University of Colorado, School of Medicine	NIH (independent research grants under peer review)†; Emergency Medicine Foundation (Mid Career Research)†	None	None	None	None	None	None
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Andrew H. Swain	Auckland University of Technology (New Zealand)	None	None	None	None	None	None	None
Lorrel E.B. Toft	University of Nevada Reno	NIGMS (NIGMS grant 2R42GM133243 will develop and investigate a novel CPR training program. I am the PI.)†	None	None	None	None	Canadian Heart & Stroke Foundation†	None
Michael Wagner	Medical University Vienna (Austria)	Austrian Research Promotion Agency (adaptive VR simulation based on real time cognitive load)†; Medical-Science Fund of the Mayor of Vienna (real-time point-of-view teaching)†; ESPNIC Medtronic Research Grant (tidal volume assessment in real time)*	Monivent (respiratory function monitoring; study nurse support and supply of equipment)†	None	None	None	None	None
Jefferson G. Williams	University of North Carolina at Chapel Hill	None	None	None	None	None	None	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $5000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $5000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

Reporting Categories and Definitions

Reporting category	Definition
Consultant	Relationships for which honoraria are allocated or received from private sector payers, pharmaceutical, device, or other mission-related companies, gifts, or other consideration, or "in kind" compensation, including fees donated to nonprofit organizations, whether for consulting, lecturing, traveling, service on advisory boards, or similar activities in the reporting period (12 months before the date of the kickoff meeting). This includes consulting or advisory activities for federal, state, or local government agencies such as Centers for Medicare & Medicaid Services (CMS) or the US Food and Drug Administration (FDA). Because the federal government maintains procedures to assure freedom from bias, consulting for its agencies is generally not classified as relevant to American Heart Association (AHA)/American College of Cardiology (ACC) document development.
Speaker or member of speakers' bureau	Honoraria or fees received directly from industry for lecturing. Compensation received through contracts with industry or other entities for membership on or participation in speakers bureaus (both domestic and international). Honoraria or fees received from an accredited continuing medical education (CME) program organized through certified educational organizations need not be disclosed. Food and beverage payments related to a single instance with a single company for ≤$250.00 is not considered a relevant relationship with industry (RWI). In addition, it will not be considered a relevant RWI if the total payments for food and beverage received from all relevant companies do not exceed $1000.00 during the reporting timeframe (see Section 2.1.1).
Ownership/partnership/principal	Stock holdings,* stock options,* ownership, partnership, membership, or other equity positions, regardless of the form of the entity, or options or rights to acquire such positions, rights, or royalties in patents or other intellectual property. Ownership of interests in diversified mutual funds is excluded from this designation and need not be reported.
Personal research	Roles as principal investigator (PI), co-PI, or investigator at a local, national or international level, steering committee member or consultant for grants pending, awarded, or received (including commercially funded, National Institutes of Health [NIH]– or other federal agency-funded, and university-managed grants and Data Monitoring Committee (DMC, Data Safety Monitoring Board [DSMB]), Clinical Event Adjudication Committee (CEAC; Clinical End-Point Committee [CEC]) activities, and other operational activities related to research. This category includes receipt of drugs, supplies, equipment, or other support when the individual has direct decision-making responsibility for allocated resources or proceeds. This type of relationship should be reported by the individual even when funds are budgeted to an institution. For investigators, subinvestigators,†, or coinvestigators† (as defined below), affirmative responses to any question in the definition indicate responsibility to report. Research activity funded by the NIH or other federal agency should be reported but is generally not classified as relevant to AHA/ACC document development.
Employment or salary support	Full or partial employment or grant support of salary, position, or program; may also include pension or benefits received from prior employment.
Institutional or organizational (including but not limited to research)	This category refers to relationships between industry and an institution or organization with which the individual is affiliated when the individual is involved in the relationship. The individual should report RWI when funds provided to an academic institution or organization are designated for the use of the individual rather than awarded or paid directly to the individual. For example, an individual participating as a coinvestigator or subsidiary investigator in a study for which another individual is designated as the grant awardee or funded PI is an example of this type of relationship, which should be disclosed. When industry funds an institution for other purposes (eg, to support a program or fellowship), the determining consideration is whether the reporting individual has decision-making responsibility over the funds. Examples of RWI that should be reported include (1) serving as an investigator, subinvestigator†, or coinvestigator† (as defined below) when the individual engages in or oversees recruitment of subjects to participate in a clinical trial; (2) a department chair or division chief with fiscal authority or decision-making responsibility over funds received from extramural sources for research, fellowships, educational conferences, institutional supplies; and (3) funds provided by a commercial entity to an institution with which the individual has a professional or personal affiliation (eg, faculty of a medical school) when the funds provide full or partial salary support of the individual or staff under the direction of the individual. These relationships may be considered relevant to the writing effort (see Section 2.1.5), whereas research or clinical funding obtained from federal sources (eg, grant support from NIH or other government agency) is not considered relevant, even when the government has received support from industry for the project. Other relationships that should be reported include leadership or governance responsibilities or roles (eg, officer, director, trustee or other fiduciary role, editor) in professional or nonprofit organizations, regardless of whether remunerated, that may involve interests potentially competitive with the AHA or AHA or cooperative or competitive with entities having business interests in the guideline topic.
Expert witness	Legal proceedings in which the individual served as a consultant, expert, or deposed witness, whether compensated or uncompensated, should be disclosed, reporting the year of involvement, alignment with the plaintiff or defendant, and the topic of the case/testimony, and whether the matter proceeded to trial. Disclosure should be consistent with applicable legal requirements and restrictions such as HIPAA or confidentiality agreements.

The above definitions describe the categories or types of relationships used for relationships with industry reporting, clarifying expectations for disclosure and general determinations for relevance.

*Divesting publicly traded stock or stock options nullifies the specific relationship, and in such cases, the 12-month rule does not apply.

†Subinvestigators or coinvestigators are defined here as individuals who have signed FDA Form 1572 or an Investigator Agreement in roles other than primary or coauthor of data analyses, abstracts, or manuscripts; who do not have oversight of the research, report data, or receive compensation from the sponsor (including direct salary support or salary support for staff, shared staff, or overhead charges); and do not receive funds for travel or accommodation to attend investigator meetings hosted by the sponsor.

Subinvestigators or coinvestigators should answer 3 questions: (1) Have you signed an FDA Form 1572 or an Investigator Agreement? (2) Do you have oversight of the research or data reporting? (3) Did you receive funds or compensation to attend investigator meetings? If the answer to any of these is affirmative, the relationship should be disclosed under the personal research category; if all answers are negative, the relationship should be disclosed under the institutional category.

Clinical trial enrollers who have signed an FDA Form 1572 but only apply study inclusion or exclusion criteria to enroll clinical patients in studies are not considered to have a relevant relationship with the study sponsor.

Data Monitoring Activities for Clinical Trials.

Membership on DMCs, DSMBs, CEACs, or CECs, whether commercially funded or government or university managed, are not classified as relevant relationships when the committee is independent of industry influence, as recommended by the FDA. The AHA/ACC recognizes that the main responsibility of the DMC is to ensure the safety of trial participants and the scientific integrity of the study in the interest of advancing clinical research. DMC membership should be reported on the member's comprehensive disclosure. The oversight Joint Committee will review the DMC Charter to ensure compliance with FDA regulations regarding independence from influence by a commercial sponsor, in which case the relationship will not be considered relevant to the document under development.

REFERENCES

1. International Liaison Committee on Resuscitation. ILCOR website. Accessed February 20, 2023. https://ilcor.org/
2. Guyatt G, Oxman AD, Akl EA, Kunz R, Vist G, Brozek J, Norris S, Falck-Ytter Y, Glasziou P, DeBeer H, et al. GRADE guidelines: 1, introduction–GRADE evidence profiles and summary of findings tables. *J Clin Epidemiol*. 2011;64:383–394. doi: 10.1016/j.jclinepi.2010.04.026
3. Bierens J, Abelairas-Gomez C, Barcala Furelos R, Beerman S, Claesson A, Dunne C, Elsenga HE, Morgan P, Mecrow T, Pereira JC, et al. Resuscitation and emergency care in drowning: a scoping review. *Resuscitation*. 2021;162:205–217. doi: 10.1016/j.resuscitation.2021.01.033
4. Olasveengen TM, Mancini ME, Perkins GD, Avis S, Brooks S, Castren M, Chung SP, Considine J, Couper K, Escalante R, et al; Adult Basic Life Support Collaborators. Adult basic life support: International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*. 2020;156:A35–A79. doi: 10.1016/j.resuscitation.2020.09.010
5. Olasveengen TM, Mancini ME, Perkins GD, Avis S, Brooks S, Castren M, Chung SP, Considine J, Couper K, Escalante R, et al; Adult Basic Life Support Collaborators. Adult basic life support: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2020;142:S41–S91. doi: 10.1161/CIR.0000000000000892
6. Barcala-Furelos R, Schmidt A, Webber J, Perkins G, Bierens J, Bray J; International Liaison Committee on Resuscitation Basic Life Support Task Force. Immediate resuscitation in-water or delaying until on land strategies for drowning: Consensus on Science With Treatment Recommendations. Accessed January 15, 2023. https://costr.ilcor.org/document/immediate-resuscitation-in-water-or-delaying-on-land-in-drowning-bls-tf-sr
7. Szpilman D, Soares M. In-water resuscitation: is it worthwhile? *Resuscitation*. 2004;63:25–31. doi: 10.1016/j.resuscitation.2004.03.017
8. International Liaison Committee on Resuscitation. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations, part 2: adult basic life support. *Resuscitation*. 2005;67:187–201. doi: 10.1016/j.resuscitation.2005.09.016
9. International Liaison Committee on Resuscitation. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations, part 2: adult basic life support. *Circulation*. 2005;112:III-5–III-16. doi: 10.1161/CIRCULATIONAHA.105.166472
10. Szpilman D, Morgan PJ. Management for the drowning patient. *Chest*. 2021;159:1473–1483. doi: 10.1016/j.chest.2020.10.007
11. March NF, Matthews RC. New techniques in external cardiac compressions: aquatic cardiopulmonary resuscitation. *JAMA*. 1980;244:1229–1232.
12. Winkler BE, Eff AM, Ehrmann U, Eff S, Koch A, Kaehler W, Georgieff M, Muth CM. Effectiveness and safety of in-water resuscitation performed by lifeguards and laypersons: a crossover manikin study. *Prehosp Emerg Care*. 2013;17:409–415. doi: 10.3109/10903127.2013.792892
13. Winkler BE, Eff AM, Eff S, Ehrmann U, Koch A, Kahler W, Muth CM. Efficacy of ventilation and ventilation adjuncts during in-water-resuscitation: a randomized cross-over trial. *Resuscitation*. 2013;84:1137–1142. doi: 10.1016/j.resuscitation.2013.02.006
14. Perkins GD. In-water resuscitation: a pilot evaluation. *Resuscitation*. 2005;65:321–324. doi: 10.1016/j.resuscitation.2004.12.002
15. Manolios N, Mackie I. Drowning and near-drowning on Australian beaches patrolled by life-savers: a 10-year study, 1973-1983. *Med J Aust*. 1988;148:165–171.
16. Lungwitz YP, Nussbaum BL, Paulat K, Muth CM, Kranke P, Winkler BE. A novel rescue-tube device for in-water resuscitation. *Aerosp Med Hum Perform*. 2015;86:379–385. doi: 10.3357/AMHP.4133.2015
17. Seesink J, Nieuwenburg SAV, van der Linden T, Bierens J. Circumstances, outcome and quality of cardiopulmonary resuscitation by lifeboat crews. *Resuscitation*. 2019;142:104–110. doi: 10.1016/j.resuscitation.2019.07.012
18. Fungueirino-Suarez R, Barcala-Furelos R, Gonzalez-Fermoso M, Martinez-Isasi S, Fernandez-Mendez F, Gonzalez-Salvado V, Navarro-Paton R, Rodriguez-Nunez A. Coastal fishermen as lifesavers while sailing at high speed: a crossover study. *Biomed Res Int*. 2018;2018:Artn 2747046. doi: 10.1155/2018/2747046
19. Tipton M, David G, Eglin C, Golden F. Basic life support on small boats at sea. *Resuscitation*. 2007;75:332–337. doi: 10.1016/j.resuscitation.2007.04.027
20. Venema AM, Sahinovic MM, Ramaker AJDWR, van de Riet YN, Absalom AR, Wietasch JKG. Performance of basic life support by lifeboat crewmembers while wearing a survival suit and life vest: a randomized controlled trial. *Front Public Health*. 2021;9:ARTN 666553. doi: 10.3389/fpubh.2021.666553
21. Barcala-Furelos R, Abelairas-Gomez C, Palacios-Aguilar J, Rey E, Costas-Veiga J, Lopez-Garcia S, Rodriguez-Nunez A. Can surf-lifeguards perform a quality cardiopulmonary resuscitation sailing on a lifeboat? A quasi-experimental study. *Emerg Med J*. 2017;34:370. doi: 10.1136/emermed-2016-205952
22. Barcala-Furelos R, Abelairas-Gómez C, Alonso-Calvete A, Cano-Noguera F, Carballo-Fazanes A, Martínez-Isasi S, Rodríguez-Núñez A. Safe onboat resuscitation by lifeguards in COVID-19 era: a pilot study comparing three sets of personal protective equipment. *Prehosp Disaster Med*. 2021;36:163–169. doi: 10.1017/S1049023X2100011X
23. Idris AH, Bierens J, Perkins GD, Wenzel V, Nadkarni V, Morley P, Warner DS, Topjian A, Venema AM, Branche CM, et al. 2015 Revised Utstein-style recommended guidelines for uniform reporting of data from drowning-related resuscitation: an ILCOR advisory statement. *Resuscitation*. 2017;118:147–158. doi: 10.1016/j.resuscitation.2017.05.028
24. Idris AH, Bierens J, Perkins GD, Wenzel V, Nadkarni V, Morley P, Warner DS, Topjian A, Venema AM, Branche CM, et al. 2015 Revised Utstein-style recommended guidelines for uniform reporting of data from drowning-related resuscitation: an ILCOR advisory statement. *Circ Cardiovasc Qual Outcomes*. 2017;10:e000024. doi: 10.1161/HCQ.0000000000000024
25. Meaney PA, Bobrow BJ, Mancini ME, Christenson J, de Caen AR, Bhanji F, Abella BS, Kleinman ME, Edelson DP, Berg RA, et al. Cardiopulmonary resuscitation quality: improving cardiac resuscitation outcomes both inside and outside the hospital: a consensus statement from the American Heart Association [published corrections appear in *Circulation*. 2013;128:e120 and *Circulation*. 2013;128:e408]. *Circulation*. 2013;128:417–435. doi: 10.1161/CIR.0b013e31829d8654
26. Haywood K, Whitehead L, Nadkarni VM, Achana F, Beesems S, Bottiger BW, Brooks A, Castren M, Ong ME, Hazinski MF, et al; COSCA Collaborators. COSCA (Core Outcome Set for Cardiac Arrest) in adults: an advisory statement from the International Liaison Committee on Resuscitation. *Circulation*. 2018;137:e783–e801. doi: 10.1161/CIR.0000000000000562
27. Haywood K, Whitehead L, Nadkarni VM, Achana F, Beesems S, Bottiger BW, Brooks A, Castren M, Ong MEH, Hazinski MF, et al; COSCA Collaborators. COSCA (Core Outcome Set for Cardiac Arrest) in adults: an advisory statement from the International Liaison Committee on Resuscitation. *Resuscitation*. 2018;127:147–163. doi: 10.1016/j.resuscitation.2018.03.022
28. Beerman S, Beerman T, Fukuda T, Bierens J, Olasveengen T, Bray J, Morley PT, Perkins GD; International Liaison Committee on Resuscitation Basic Life Support Task Force. AED first vs CPR first for drowning: Consensus on Science With Treatment Recommendations. Accessed January 15, 2022. https://costr.ilcor.org/document/aed-first-vs-cpr-first-in-cardiac-arrest-following-drowning-bls-856
29. Bierens JJ, Lunetta P, Tipton M, Warner DS. Physiology of drowning: a review. *Physiology (Bethesda)*. 2016;31:147–166. doi: 10.1152/physiol.00002.2015
30. Kiyohara K, Sado J, Matsuyama T, Nishiyama C, Kobayashi D, Kiguchi T, Hayashida S, Kitamura Y, Sobue T, Nakata K, et al. Out-of-hospital cardiac arrests during exercise among urban inhabitants in Japan: insights from a population-based registry of Osaka City. *Resuscitation*. 2017;117:14–17. doi: 10.1016/j.resuscitation.2017.05.025
31. Holmberg MJ, Vognsen M, Andersen MS, Donnino MW, Andersen LW. Bystander automated external defibrillator use and clinical outcomes after out-of-hospital cardiac arrest: a systematic review and meta-analysis. *Resuscitation*. 2017;120:77–87. doi: 10.1016/j.resuscitation.2017.09.003
32. Abelairas-Gómez C, Tobin JM, Jayashree M, Bierens J, Olasveengen T, Bray J, Morley PT, Perkins GD; International Liaison Committee on Resuscitation Basic Life Support Task Force. Ventilation strategies (with vs without equipment) following drowning: Consensus on Science With Treatment Recommendations. Accessed January 15, 2023. https://costr.ilcor.org/document/ventilation-with-vs-without-equipment-before-hospital-arrival-following-drowning-bls-tfsr
33. Soar J, Maconochie I, Wyckoff MH, Olasveengen TM, Singletary EM, Greif R, Aickin R, Bhanji F, Donnino MW, Mancini ME, et al. 2019 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: summary from the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces. *Circulation*. 2019;140:e826–e880. doi: 10.1161/CIR.0000000000000734
34. Soar J, Maconochie I, Wyckoff MH, Olasveengen TM, Singletary EM, Greif R, Aickin R, Bhanji F, Donnino MW, Mancini ME, et al. 2019 International

Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*. 2019;145:95–150. doi: 10.1016/j.resuscitation.2019.10.016
35. Ryan KM, Bui MD, Dugas JN, Zvonar I, Tobin JM. Impact of prehospital airway interventions on outcome in cardiac arrest following drowning: a study from the CARES Surveillance Group. *Resuscitation*. 2021;163:130–135. doi: 10.1016/j.resuscitation.2020.12.027
36. Baker PA, Webber JB. Failure to ventilate with supraglottic airways after drowning. *Anaesth Intensive Care*. 2011;39:675–677. doi: 10.1177/0310057X1103900423
37. Joanknecht L, Argent AC, van Dijk M, van As AB. Childhood drowning in South Africa: local data should inform prevention strategies. *Pediatr Surg Int*. 2015;31:123–130. doi: 10.1007/s00383-014-3637-0
38. Kieboom JK, Verkade HJ, Burgerhof JG, Bierens JJ, Rheenen PF, Kneyber MC, Albers MJ. Outcome after resuscitation beyond 30 minutes in drowned children with cardiac arrest and hypothermia: Dutch nationwide retrospective cohort study. *BMJ*. 2015;350:h418. doi: 10.1136/bmj.h418
39. Maconochie IK, Aickin R, Hazinski MF, Atkins DL, Bingham R, Couto TB, Guerguerian AM, Nadkarni VM, Ng KC, Nuthall GA, et al; Pediatric Life Support Collaborators. Pediatric life support: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*. 2020;156:A120–A155. doi: 10.1016/j.resuscitation.2020.09.013
40. Maconochie IK, Aickin R, Hazinski MF, Atkins DL, Bingham R, Couto TB, Guerguerian AM, Nadkarni VM, Ng KC, Nuthall GA, et al; Pediatric Life Support Collaborators. Pediatric life support: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2020;142:S140–S184. doi: 10.1161/CIR.0000000000000894
41. Olasveengen TM, Mancini ME, Perkins GD, Avis S, Brooks S, Castrén M, Chung SP, Considine J, Couper K, Escalante R, et al; Adult Basic Life Support Collaborators. Adult basic life support: International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*. 2020;156:A35–A79. doi: 10.1016/j.resuscitation.2020.09.010
42. Olasveengen TM, Semeraro F, Ristagno G, Castren M, Handley A, Kuzovlev A, Monsieurs KG, Raffay V, Smyth M, Soar J, et al. European Resuscitation Council Guidelines 2021: basic life support. *Resuscitation*. 2021;161:98–114. doi: 10.1016/j.resuscitation.2021.02.009
43. Abelairas-Gomez C, Tipton MJ, Gonzalez-Salvado V, Bierens J. Drowning: epidemiology, prevention, pathophysiology, resuscitation, and hospital treatment. *Emergencias*. 2019;31:270–280.
44. Sempsrott J, Szpilman D, Liu L, Bierens J, Bray J, Perkins GD, International Liaison Committee on Resuscitation Basic Life Support Task Force. Compression-only CPR vs standard CPR with compressions and ventilations following drowning: Consensus on Science With Treatment Recommendations. Accessed January 15, 2023. https://costr.ilcor.org/document/chest-compression-cpr-versus-conventional-cpr-in-drowning-bls-tfsr
45. Fukuda T, Ohashi-Fukuda N, Hayashida K, Kondo Y, Kukita I. Bystander-initiated conventional vs compression-only cardiopulmonary resuscitation and outcomes after out-of-hospital cardiac arrest due to drowning. *Resuscitation*. 2019;145:166–174. doi: 10.1016/j.resuscitation.2019.08.026
46. Tobin JM, Ramos WD, Greenshields J, Dickinson S, Rossano JW, Wernicki PG, Markenson D, Vellano K, McNally B; CARES Surveillance Group. Outcome of conventional bystander cardiopulmonary resuscitation in cardiac arrest following drowning. *Prehosp Disaster Med*. 2020;35:141–147. doi: 10.1017/S1049023X20000060
47. Bray JE, Smith K, Case R, Cartledge S, Straney L, Finn J. Public cardiopulmonary resuscitation training rates and awareness of hands-only cardiopulmonary resuscitation: a cross-sectional survey of Victorians. *Emerg Med Australas*. 2017;29:158–164. doi: 10.1111/1742-6723.12720
48. Gräsner J-T, Wnent J, Herlitz J, Perkins GD, Lefering R, Tjelmeland I, Koster RW, Masterson S, Rossell-Ortiz F, Maurer H, et al. Survival after out-of-hospital cardiac arrest in Europe: results of the EuReCa TWO study. *Resuscitation*. 2020;148:218–226. doi: 10.1016/j.resuscitation.2019.12.042
49. Lagina AT, Claesson A, Bierens J, Olasveengen T, Bray J, Morley PT, Perkins GD; International Liaison Committee on Resuscitation Basic Life Support Task Force. Public access to defibrillation following drowning: Consensus on Science With Treatment Recommendations. Accessed January 15, 2023. https://costr.ilcor.org/document/implementation-of-pad-programs-for-drowning-bls
50. Brooks SC, Clegg GR, Bray J, Deakin CD, Perkins GD, Ringh M, Smith CM, Link MS, Merchant RM, Pezo-Morales J, et al; International Liaison Committee on Resuscitation. Optimizing outcomes after out-of-hospital cardiac arrest with innovative approaches to public-access defibrillation: a scientific statement from the International Liaison Committee on Resuscitation. *Resuscitation*. 2022;172:204–228. doi: 10.1016/j.resuscitation.2021.11.032
51. Brooks SC, Clegg GR, Bray J, Deakin CD, Perkins GD, Ringh M, Smith CM, Link MS, Merchant RM, Pezo-Morales J, et al; on behalf of the International Liaison Committee on Resuscitation. Optimizing outcomes after out-of-hospital cardiac arrest with innovative approaches to public-access defibrillation: a scientific statement from the International Liaison Committee on Resuscitation. *Circulation*. 2022;145:e776–e801. doi: 10.1161/CIR.0000000000001013
52. Seesink J, Thom O, Johnson S, Bierens J, Olasveengen T, Bray J, Morley PT, Perkins GD; International Liaison Committee on Resuscitation Basic Life Support Task Force. Oxygen administration following drowning: Consensus on Science With Treatment Recommendations. Accessed January 15, 2023. https://costr.ilcor.org/document/oxygen-administration-following-drowning-bls-856
53. Bernard SA, Bray JE, Smith K, Stephenson M, Finn J, Grantham H, Hein C, Masters S, Stub D, Perkins GD, et al; EXACT Investigators. Effect of lower vs higher oxygen saturation targets on survival to hospital discharge among patients resuscitated after out-of-hospital cardiac arrest: the EXACT randomized clinical trial. *JAMA*. 2022;328:1818–1826. doi: 10.1001/jama.2022.17701
54. Holbery-Morgan L, Carew J, Angel C, Simpson N, Steinfort D, Radford S, Murphy M, Douglas N, Johnson D. Feasibility of pulse oximetry after water immersion. *Resusc Plus*. 2021;7:100147. doi: 10.1016/j.resplu.2021.100147
55. Montenij LJ, de Vries W, Schwarte L, Bierens JJ. Feasibility of pulse oximetry in the initial prehospital management of victims of drowning: a preliminary study. *Resuscitation*. 2011;82:1235–1238. doi: 10.1016/j.resuscitation.2011.04.019
56. Shi C, Goodall M, Dumville J, Hill J, Norman G, Hamer O, Clegg A, Watkins CL, Georgiou G, Hodkinson A, et al. The effects of skin pigmentation on the accuracy of pulse oximetry in measuring oxygen saturation: a systematic review and meta-analysis. *BMC Med*. 2022;20:267. doi: 10.1101/2022.02.16.22271062
57. Wyckoff MH, Greif R, Morley PT, Ng KC, Olasveengen TM, Singletary EM, Soar J, Cheng A, Drennan IR, Liley HG, et al; Collaborators. 2022 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: summary from the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces. *Resuscitation*. 2022;181:208–288. doi: 10.1016/j.resuscitation.2022.10.005
58. Wyckoff MH, Greif R, Morley PT, Ng KC, Olasveengen TM, Singletary EM, Soar J, Cheng A, Drennan IR, Liley HG, et al; Collaborators. 2022 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations: summary from the Basic Life Support; Advanced Life Support; Pediatric Life Support; Neonatal Life Support; Education, Implementation, and Teams; and First Aid Task Forces. *Circulation*. 2022;146:e483–e557. doi: 10.1161/CIR.0000000000001095
59. Couper K, Taylor-Phillips S, Grove A, Freeman K, Osokogu O, Court R, Mehrabian A, Morley PT, Nolan JP, Soar J, et al. COVID-19 in cardiac arrest and infection risk to rescuers: a systematic review. *Resuscitation*. 2020;151:59–66. doi: 10.1016/j.resuscitation.2020.04.022
60. Chung SP, Nehme Z, Johnson NJ, Lagina A, Bray J; International Liaison Committee on Resuscitation (ILCOR) Basic Life Support Task Force. Effects of personal protective equipment on cardiopulmonary resuscitation quality and outcomes: a systematic review. *Resusc Plus*. 2023;14:100398. doi: 10.1016/j.resplu.2023.100398
61. Chung SP, Nehme Z, Lagina A, Johnson N, Bray J; International Liaison Committee on Resuscitation Basic Life Support Task Force. CPR by rescuers wearing PPE vs no PPE for cardiac arrest in adults and children: Consensus on Science With Treatment Recommendations. Accessed January 15, 2023. https://costr.ilcor.org/document/cpr-by-rescuers-wearing-ppe-bls-tfsr
62. Ko HY, Park JE, Jeong DU, Shin TG, Sim MS, Jo IJ, Lee GT, Hwang SY. Impact of personal protective equipment on out-of-hospital cardiac arrest resuscitation in coronavirus pandemic. *Medicina (Kaunas)*. 2021;57:1291. doi: 10.3390/medicina57121291
63. Kienbacher CL, Grafeneder J, Tscherny K, Krammel M, Fuhrmann V, Niederer M, Neudorfsky S, Herbich K, Schreiber W, Herkner H, et al. The use of personal protection equipment does not impair the quality of cardiopulmonary resuscitation: a prospective triple-cross over randomised

controlled non-inferiority trial. *Resuscitation*. 2021;160:79–83. doi: 10.1016/j.resuscitation.2021.01.021
64. Mormando G, Paganini M, Alexopoulos C, Savino S, Bortoli N, Pomiato D, Graziano A, Navalesi P, Fabris F. Life-saving procedures performed while wearing CBRNe Personal protective equipment: a mannequin randomized trial. *Simul Healthc*. 2021;16:e200–e205. doi: 10.1097/SIH.0000000000000540
65. Rauch S, van Veelen MJ, Oberhammer R, Dal Cappello T, Roveri G, Gruber E, Strapazzon G. Effect of wearing personal protective equipment (PPE) on CPR quality in times of the COVID-19 pandemic: a simulation, randomised crossover trial. *J Clin Med*. 2021;10:1728. doi: 10.3390/jcm10081728
66. Chen J, Lu KZ, Yi B, Chen Y. Chest compression with personal protective equipment during cardiopulmonary resuscitation: a randomized crossover simulation study. *Medicine (Baltimore)*. 2016;95:e3262. doi: 10.1097/MD.0000000000003262
67. Kim TH, Kim CH, Shin SD, Haam S. Influence of personal protective equipment on the performance of life-saving interventions by emergency medical service personnel. *Simulation*. 2016;92:893–898. doi: 10.1177/0037549716662322
68. Fernández-Méndez M, Otero-Agra M, Fernández-Méndez F, Martínez-Isasi S, Santos-Folgar M, Barcala-Furelos R, Rodríguez-Núñez A. Analysis of physiological response during cardiopulmonary resuscitation with personal protective equipment: a randomized crossover study. *Int J Environ Res Public Health*. 2021;18:7093. doi: 10.3390/ijerph18137093
69. Hacımustafaoğlu M, Çağlar A, Öztürk B, Kaçer I, Öztürk K. The effect of personal protective equipment on cardiac compression quality. *African J Emerg Med*. 2021;11:385–389. doi: 10.1016/j.afjem.2021.07.004
70. Serin S, Caglar B. The effect of different personal protective equipment masks on health care workers' cardiopulmonary resuscitation performance during the Covid-19 pandemic. *J Emerg Med*. 2021;60:292–298. doi: 10.1016/j.jemermed.2020.11.005
71. Donoghue AJ, Donoghue AJ, Henretig FM, Donoghue AJ, Kou M, Good GL, Kochman A, Kou M, Stacks H, Eiger C, et al. Impact of personal protective equipment on pediatric cardiopulmonary resuscitation performance: a controlled trial. *Pediatr Emerg Care*. 2020;36:267–273. doi: 10.1097/PEC.0000000000002109
72. Shin DM, Kim SY, Shin SD, Kim CH, Kim TH, Kim K, Kim JH, Hong EJ. Effect of wearing personal protective equipment on cardiopulmonary resuscitation: focusing on 119 emergency medical technicians. *Korean J Emerg Med Service*. 2015;19:19–32.
73. Cavallin F, Lupi F, Bua B, Bellutti M, Staffler A, Trevisanuto D. Impact of personal protective equipment on neonatal resuscitation procedures: a randomised, cross-over, simulation study. *Arch Dis Child Fetal Neonatal Ed*. 2022;107:211–215. doi: 10.1136/archdischild-2021-322216
74. Watson L, Sault W, Gwyn R, Verbeek PR. The "delay effect" of donning a gown during cardiopulmonary resuscitation in a simulation model. *CJEM*. 2008;10:333–338. doi: 10.1017/s1481803500010332
75. Deleted in proof.
76. Jo CH, Cho GC, Ahn JH, Park YS, Lee CH. Rescuer-limited cardiopulmonary resuscitation as an alternative to 2-min switched CPR in the setting of inhospital cardiac arrest: a randomised cross-over study. *Emerg Med J*. 2015;32:539. doi: 10.1136/emermed-2013-203477
77. Kollander L, Folke F, Bray J; International Liaison Committee on Resuscitation Basic Life Support Task Force. Drone AEDs Task Force synthesis of a scoping Review. Accessed January 15, 2023. https://costr.ilcor.org/document/drone-aeds-bls-tf-scr
78. Bauer J, Moormann D, Strametz R, Groneberg DA. Development of unmanned aerial vehicle (UAV) networks delivering early defibrillation for out-of-hospital cardiac arrests (OHCA) in areas lacking timely access to emergency medical services (EMS) in Germany: a comparative economic study. *BMJ Open*. 2021;11:e043791. doi: 10.1136/bmjopen-2020-043791
79. Bogle B, Rosamond WD, Snyder KT, Zègre-Hemsey JK. The case for drone-assisted emergency response to cardiac arrest. *N C Med J*. 2019;80:204–212. doi: 10.18043/ncm.80.4.204
80. Boutilier JJ, Brooks SC, Janmohamed A, Byers A, Buick JE, Zhan C, Schoellig AP, Cheskes S, Morrison LJ, Chan TCY. Optimizing a drone network to deliver automated external defibrillators. *Circulation*. 2017;135:2454–2465. doi: 10.1161/CIRCULATIONAHA.116.026318
81. Choi DS, Hong KJ, Shin SD, Lee CG, Kim TH, Cho Y, Song KJ, Ro YS, Park JH, Kim KH. Effect of topography and weather on delivery of automatic electrical defibrillator by drone for out-of-hospital cardiac arrest. *Sci Rep*. 2021;11:24195. doi: 10.1038/s41598-021-03648-3
82. Chu J, Leung KHB, Snobelen P, Nevils G, Drennan IR, Cheskes S, Chan TCY. Machine learning-based dispatch of drone-delivered defibrillators for out-of-hospital cardiac arrest. *Resuscitation*. 2021;162:120–127. doi: 10.1016/j.resuscitation.2021.02.028
83. Claesson A, Fredman D, Svensson L, Ringh M, Hollenberg J, Nordberg P, Rosenqvist M, Djarv T, Österberg S, Lennartsson J, et al. Unmanned aerial vehicles (drones) in out-of-hospital-cardiac-arrest. *Scand J Trauma Resusc Emerg Med*. 2016;24:124. doi: 10.1186/s13049-016-0313-5
84. Derkenne C, Jost D, L'Espinay AMD, Corpet P, Frattini B, Hong V, Lemoine F, Jouffroy R, Roquet F, Marijon E, et al. Automatic external defibrillator provided by unmanned aerial vehicle (drone) in Greater Paris: a real world-based simulation. *Resuscitation*. 2021;162:259–265. doi: 10.1016/j.resuscitation.2021.03.012
85. Lancaster G, Herrmann J. Simulating cardiac arrest events to evaluate novel emergency response systems. *IISE Trans Healthc Syst Eng*. 2021;11:38–50. doi: 10.1080/24725579.2020.1836090
86. Lancaster G, Herrmann JW. Computer simulation of the effectiveness of novel cardiac arrest response systems. *Resusc Plus*. 2021;7:100153. doi: 10.1016/j.resplu.2021.100153
87. Leung KHB, Grunau B, Al Assil R, Heidet M, Liang LD, Deakin J, Christenson J, Cheskes S, Chan TCY. Incremental gains in response time with varying base location types for drone-delivered automated external defibrillators. *Resuscitation*. 2022;174:24–30. doi: 10.1016/j.resuscitation.2022.03.013
88. Mackle C, Bond R, Torney H, McBride R, McLaughlin J, Finlay D, Biglarbeigi P, Brisk R, Harvey A, McEneaney D. A data-driven simulator for the strategic positioning of aerial ambulance drones reaching out-of-hospital cardiac arrests: a genetic algorithmic approach. *IEEE J Transl Eng Health Med*. 2020;8:1900410. doi: 10.1109/JTEHM.2020.2987008
89. Pulver A, Wei R. Optimizing the spatial location of medical drones. *Appl Geogr*. 2018;90:9–16. doi: 10.1016/j.apgeog.2017.11.009
90. Pulver A, Wei R, Mann C. Locating AED enabled medical drones to enhance cardiac arrest response times. *Prehosp Emerg Care*. 2016;20:378–389. doi: 10.3109/10903127.2015.1115932
91. Roper JWA, Fischer K, Baumgarten MC, Thies KC, Hahnenkamp K, Flessa S. Can drones save lives and money? An economic evaluation of airborne delivery of automated external defibrillators. *Eur J Health Econ*. 2023;24:1141–1150. doi: 10.1007/s10198-022-01531-0
92. Schierbeck S, Nord A, Svensson L, Rawshani A, Hollenberg J, Ringh M, Forsberg S, Nordberg P, Hilding F, Claesson A. National coverage of out-of-hospital cardiac arrests using automated external defibrillator-equipped drones: a geographical information system analysis. *Resuscitation*. 2021;163:136–145. doi: 10.1016/j.resuscitation.2021.02.040
93. Wankmüller C, Truden C, Korzen C, Hungerländer P, Kolesnik E, Reiner G. Optimal allocation of defibrillator drones in mountainous regions. *OR Spectrum*. 2020;42:785–814. doi: 10.1007/s00291-020-00575-z
94. Baumgarten MC, Röper J, Hahnenkamp K, Thies K-C. Drones delivering automated external defibrillators: integrating unmanned aerial systems into the chain of survival: a simulation study in rural Germany. *Resuscitation*. 2022;172:139–145. doi: 10.1016/j.resuscitation.2021.12.025
95. Cheskes S, McLeod SL, Nolan M, Snobelen P, Vaillancourt C, Brooks SC, Dainty KN, Chan TCY, Drennan IR. Improving access to automated external defibrillators in rural and remote settings: a drone delivery feasibility study. *J Am Heart Association*. 2020;9:e016687. doi: 10.1161/JAHA.120.016687
96. Claesson A, Bäckman A, Ringh M, Svensson L, Nordberg P, Djärv T, Hollenberg J. Time to delivery of an automated external defibrillator using a drone for simulated out-of-hospital cardiac arrests vs emergency medical services. *JAMA*. 2017;317:2332. doi: 10.1001/jama.2017.3957
97. Kim H-J, Kim J-H, Park D. Comparing audio- and video-delivered instructions in dispatcher-assisted cardiopulmonary resuscitation with drone-delivered automatic external defibrillator: a mixed methods simulation study. *PeerJ*. 2021;9:e11761. doi: 10.7717/peerj.11761
98. Rees N, Howitt J, Breyley N, Geoghegan P, Powel C. A simulation study of drone delivery of automated external defibrillator (AED) in out of hospital cardiac arrest (OHCA) in the UK. *PLoS One*. 2021;16:e0259555. doi: 10.1371/journal.pone.0259555
99. Rosamond WD, Johnson AM, Bogle BM, Arnold E, Cunningham CJ, Picinich M, Williams BM, Zegre-Hemsey JK. Drone delivery of an automated external defibrillator. *N Engl J Med*. 2020;383:1186–1188. doi: 10.1056/NEJMc1915956
100. Sanfridsson J, Sparrevik J, Hollenberg J, Nordberg P, Djärv T, Ringh M, Svensson L, Forsberg S, Nord A, Andersson-Hagiwara M, et al. Drone delivery of an automated external defibrillator: a mixed method simulation study of bystander experience. *Scand J Trauma Resusc Emerg Med*. 2019;27:40. doi: 10.1186/s13049-019-0622-6
101. Sedig K, Seaton MB, Drennan IR, Cheskes S, Dainty KN. "Drones are a great idea! What is an AED?" Novel insights from a qualitative study on public perception of using drones to deliver

automatic external defibrillators. *Resusc Plus*. 2020;4:100033. doi: 10.1016/j.resplu.2020.100033
102. Zègre-Hemsey JK, Grewe ME, Johnson AM, Arnold E, Cunningham CJ, Bogle BM, Rosamond WD. Delivery of automated external defibrillators via drones in simulated cardiac arrest: users' experiences and the human-drone interaction. *Resuscitation*. 2020;157:83–88. doi: 10.1016/j.resuscitation.2020.10.006
103. Schierbeck S, Hollenberg J, Nord A, Svensson L, Nordberg P, Ringh M, Forsberg S, Lundgren P, Axelsson C, Claesson A. Automated external defibrillators delivered by drones to patients with suspected out-of-hospital cardiac arrest. *Eur Heart J*. 2022;43:1478–1487. doi: 10.1093/eurheartj/ehab498
104. Schierbeck S, Svensson L, Claesson A. Use of a drone-delivered automated external defibrillator in an out-of-hospital cardiac arrest. *N Engl J Med*. 2022;386:1953–1954. doi: 10.1056/NEJMc2200833
105. Holmberg MJ, Geri G, Wiberg S, Guerguerian AM, Donnino MW, Nolan JP, Deakin CD, Andersen LW; International Liaison Committee on Resuscitation's (ILCOR) Advanced Life Support and Pediatric Task Force. Extracorporeal cardiopulmonary resuscitation for cardiac arrest: a systematic review. *Resuscitation*. 2018;131:91–100. doi: 10.1016/j.resuscitation.2018.07.029
106. Holmberg MJ, Granfeldt A, Guerguerian AM, Sandroni C, Hsu CH, Gardner RM, Lind PC, Eggertsen MA, Johannsen CM, Andersen LW. Extracorporeal cardiopulmonary resuscitation for cardiac arrest: an updated systematic review. *Resuscitation*. 2023;182:109665. doi: 10.1016/j.resuscitation.2022.12.003
107. ILCOR Advanced Life Support Adult Task Force. Extracorporeal cardiopulmonary resuscitation (ECPR) for cardiac arrest: ALS TFSR. Updated January 19, 2023. Accessed February 22, 2023. https://costr.ilcor.org/document/extracorporeal-cardiopulmonary-resuscitation-ecpr-for-cardiac-arrest-als-tfsr
108. Yannopoulos D, Bartos J, Raveendran G, Walser E, Connett J, Murray TA, Collins G, Zhang L, Kalra R, Kosmopoulos M, et al. Advanced reperfusion strategies for patients with out-of-hospital cardiac arrest and refractory ventricular fibrillation (ARREST): a phase 2, single centre, open-label, randomised controlled trial. *Lancet*. 2020;396:1807–1816. doi: 10.1016/S0140-6736(20)32338-2
109. Hsu CH, Meurer WJ, Domeier R, Fowler J, Whitmore SP, Bassin BS, Gunnerson KJ, Haft JW, Lynch WR, Nallamothu BK, et al. Extracorporeal Cardiopulmonary Resuscitation for Refractory Out-of-Hospital Cardiac Arrest (EROCA): results of a randomized feasibility trial of expedited out-of-hospital transport. *Ann Emerg Med*. 2021;78:92–101. doi: 10.1016/j.annemergmed.2020.11.011
110. Belohlavek J, Rob D, Smalcova J. Effect of intra-arrest transport and extracorporeal cardiopulmonary resuscitation on functional neurologic outcome in refractory out-of-hospital cardiac arrest: reply. *JAMA*. 2022;327:2357. doi: 10.1001/jama.2022.6548
111. Deakin CD, Morley P, Soar J, Drennan IR. Double (dual) sequential defibrillation for refractory ventricular fibrillation cardiac arrest: a systematic review. *Resuscitation*. 2020;155:24–31. doi: 10.1016/j.resuscitation.2020.06.008
112. Ohshimo S, Drennan I, Deakin CD, Soar J, Berg KM; International Liaison Committee on Resuscitation Advanced Life Support Task Force. Double sequential defibrillation strategy for cardiac arrest with refractory shockable rhythm: ALS TFSR. Updated December 5, 2022. Accessed February 22, 2023. https://costr.ilcor.org/document/header-double-sequence-defibrillation-task-force-systematic-review-costr
113. Cheskes S, Dorian P, Feldman M, McLeod S, Scales DC, Pinto R, Turner L, Morrison LJ, Drennan IR, Verbeek PR. Double sequential external defibrillation for refractory ventricular fibrillation: the DOSE VF pilot randomized controlled trial. *Resuscitation*. 2020;150:178–184. doi: 10.1016/j.resuscitation.2020.02.010
114. Cheskes S, Verbeek PR, Drennan IR, McLeod SL, Turner L, Pinto R, Feldman M, Davis M, Vaillancourt C, Morrison LJ, et al. Defibrillation strategies for refractory ventricular fibrillation. *N Engl J Med*. 2022;387:1947–1956. doi: 10.1056/NEJMoa2207304
115. de Latorre F, Nolan J, Robertson C, Chamberlain D, Baskett P; European Resuscitation Council. European Resuscitation Council guidelines 2000 for adult advanced life support. a statement from the Advanced Life Support Working Group and approved by the Executive Committee of the European Resuscitation Council. *Resuscitation*. 2001;48:211–221. doi: 10.1016/s0300-9572(00)00379-8
116. Morrison LJ, Deakin CD, Morley PT, Callaway CW, Kerber RE, Kronick SL, Lavonas EJ, Link MS, Neumar RW, Otto CW, et al; Advanced Life Support Chapter Collaborators. Part 8: advanced life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2010;122(suppl 2):S345–S421. doi: 10.1161/CIRCULATIONAHA.110.971051
117. Vallentin MF, Granfeldt A, Meilandt C, Povlsen AL, Sindberg B, Holmberg MJ, Iversen BN, Maerkedahl R, Mortensen LR, Nyboe R, et al. Effect of intravenous or intraosseous calcium vs saline on return of spontaneous circulation in adults with out-of-hospital cardiac arrest: a randomized clinical trial. *JAMA*. 2021;326:2268–2276. doi: 10.1001/jama.2021.20929
118. Hsu CH, Couper K, Nix T, Drennan I, Reynolds J, Kleinman M, Berg KM, Advanced Life S; Paediatric Life Support Task Forces at the International Liaison Committee on Resuscitation. Calcium during cardiac arrest: a systematic review. *Resusc Plus*. 2023;14:100379. doi: 10.1016/j.resplu.2023.100379
119. Hsu CH, Couper K, Nix T, Drennan I, Reynolds J, Kleinman M, Berg KM; Advanced Life Support and Paediatric Life Support Task Forces at the International Liaison Committee on Resuscitation. Calcium during cardiac arrest: ALS TFSR. Updated December 6, 2022. Accessed February 22, 2023. https://costr.ilcor.org/document/calcium-during-cardiac-arrest-als-tfsr
120. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. The effectiveness of calcium chloride in refractory electromechanical dissociation. *Ann Emerg Med*. 1985;14:626–629. doi: 10.1016/s0196-0644(85)80874-x
121. Stueven HA, Thompson B, Aprahamian C, Tonsfeldt DJ, Kastenson EH. Lack of effectiveness of calcium chloride in refractory asystole. *Ann Emerg Med*. 1985;14:630–632. doi: 10.1016/s0196-0644(85)80875-1
122. Vallentin MF, Granfeldt A, Meilandt C, Povlsen AL, Sindberg B, Holmberg MJ, Iversen BN, Maerkedahl R, Mortensen LR, Nyboe R, et al. Effect of calcium vs. placebo on long-term outcomes in patients with out-of-hospital cardiac arrest. *Resuscitation*. 2022;179:21–24. doi: 10.1016/j.resuscitation.2022.07.034
123. Berg KM, Soar J, Andersen LW, Bottiger BW, Cacciola S, Callaway CW, Couper K, Cronberg T, D'Arrigo S, Deakin CD, et al; Adult Advanced Life Support Collaborators. Adult advanced life support: International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*. 2020;156:A80–A119. doi: 10.1016/j.resuscitation.2020.09.012
124. Berg KM, Soar J, Andersen LW, Bottiger BW, Cacciola S, Callaway CW, Couper K, Cronberg T, D'Arrigo S, Deakin CD, et al; Adult Advanced Life Support Collaborators. Adult advanced life support: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2020;142:S92–S139. doi: 10.1161/CIR.0000000000000893
125. Sandroni C, D'Arrigo S, Cacciola S, Hoedemaekers CWE, Westhall E, Kamps MJA, Taccone FS, Poole D, Meijer FJA, Antonelli M, et al. Prediction of good neurological outcome in comatose survivors of cardiac arrest: a systematic review. *Intensive Care Med*. 2022;48:389–413. doi: 10.1007/s00134-022-06618-z
126. Steinberg A, Callaway CW, Arnold RM, Cronberg T, Naito H, Dadon K, Chae MK, Elmer J. Prognostication after cardiac arrest: results of an international, multi-professional survey. *Resuscitation*. 2019;138:190–197. doi: 10.1016/j.resuscitation.2019.03.016
127. Skrifvars M, Sandroni C, Hirsch K; ILCOR Advanced Life Support Task Force. Use of the Glasgow Coma Scale motor score for the prediction of good outcome after cardiac arrest: ALS TFSR. Updated February 1, 2023. Accessed February 22, 2023. https://costr.ilcor.org/document/use-of-the-glasgow-coma-scale-motor-score-for-the-prediction-of-good-outcome-after-cardiac-arrest-als-tfsr
128. Moseby-Knappe M, Westhall E, Backman S, Mattsson-Carlgren N, Dragancea I, Lybeck A, Friberg H, Stammet P, Lilja G, Horn J, et al. Performance of a guideline-recommended algorithm for prognostication of poor neurological outcome after cardiac arrest. *Intensive Care Med*. 2020;46:1852–1862. doi: 10.1007/s00134-020-06080-9
129. Hifumi T, Kuroda Y, Kawakita K, Sawano H, Tahara Y, Hase M, Nishioka K, Shirai S, Hazui H, Arimoto H, et al; J-PULSE-Hypo Investigators. Effect of admission Glasgow Coma Scale motor score on neurological outcome in out-of-hospital cardiac arrest patients receiving therapeutic hypothermia. *Circ J*. 2015;79:2201–2208. doi: 10.1253/circj.CJ-15-0308
130. Sandroni C, Skrifvars M, Humaloja J, Hirsch K; ILCOR Advanced Life Support Task Force. Imaging for prediction of good neurological outcome: ALS TFSR. Updated February 1, 2023. Accessed February 22, 2023. https://costr.ilcor.org/document/imaging-for-prediction-of-good-neurological-outcome-als-tfsr

131. Lee KS, Lee SE, Choi JY, Gho YR, Chae MK, Park EJ, Choi MH, Hong JM. Useful computed tomography score for estimation of early neurologic outcome in post-cardiac arrest patients with therapeutic hypothermia. *Circ J*. 2017;81:1628–1635. doi: 10.1253/circj.CJ-16-1327
132. Jang J, Oh SH, Nam Y, Lee K, Choi HS, Jung SL, Ahn KJ, Park KN, Kim BS. Prognostic value of phase information of 2D T2*-weighted gradient echo brain imaging in cardiac arrest survivors: a preliminary study. *Resuscitation*. 2019;140:142–149. doi: 10.1016/j.resuscitation.2019.05.026
133. Oh SH, Park KN, Choi SP, Oh JS, Kim HJ, Youn CS, Kim SH, Chang K, Kim SH. Beyond dichotomy: patterns and amplitudes of SSEPs and neurological outcomes after cardiac arrest. *Crit Care*. 2019;23:224. doi: 10.1186/s13054-019-2510-x
134. Park JS, In YN, You YH, Min JH, Ahn HJ, Yoo IS, Kim SW, Lee JW, Ryu S, Jeong WJ, et al. Ultra-early neurologic outcome prediction of out-of-hospital cardiac arrest survivors using combined diffusion-weighted imaging findings and quantitative analysis of apparent diffusion coefficient. *Resuscitation*. 2020;148:39–48. doi: 10.1016/j.resuscitation.2019.12.021
135. Mlynash M, Campbell DM, Leproust EM, Fischbein NJ, Bammer R, Eyngorn I, Hsia AW, Moseley M, Wijman CA. Temporal and spatial profile of brain diffusion-weighted MRI after cardiac arrest. *Stroke*. 2010;41:1665–1672. doi: 10.1161/STROKEAHA.110.582452
136. Wouters A, Scheldeman L, Plessers S, Peeters R, Cappelle S, Demaerel P, Van Paesschen W, Ferdinande B, Dupont M, Dens J, et al. Added value of quantitative apparent diffusion coefficient values for neuroprognostication after cardiac arrest. *Neurology*. 2021;96:e2611–e2618. doi: 10.1212/WNL.0000000000011991
137. Skrifvars M, Humaloja J, Sandroni C, Hirsch K; ILCOR Advanced Life Support Task Force. Use of brain injury biomarkers for the prediction of good outcome after cardiac arrest: ALS TFSR. Accessed February 22, 2023. https://costr.ilcor.org/document/use-of-brain-injury-biomarkers-for-the-prediction-of-good-outcome-after-cardiac-arrest-als-tfsr
138. Zellner T, Gartner R, Schopohl J, Angstwurm M. NSE and S-100B are not sufficiently predictive of neurologic outcome after therapeutic hypothermia for cardiac arrest. *Resuscitation*. 2013;84:1382–1386. doi: 10.1016/j.resuscitation.2013.03.021
139. Moseby-Knappe M, Mattsson-Carlgren N, Stammet P, Backman S, Blennow K, Dankiewicz J, Friberg H, Hassager C, Horn J, Kjaergaard J, et al. Serum markers of brain injury can predict good neurological outcome after out-of-hospital cardiac arrest. *Intensive Care Med*. 2021;47:984–994. doi: 10.1007/s00134-021-06481-4
140. Streitberger KJ, Leithner C, Wattenberg M, Tonner PH, Hasslacher J, Joannidis M, Pellis T, Di Luca E, Fodisch M, Krannich A, et al. Neuron-specific enolase predicts poor outcome after cardiac arrest and targeted temperature management: a multicenter study on 1,053 patients. *Crit Care Med*. 2017;45:1145–1151. doi: 10.1097/CCM.0000000000002335
141. Wihersaari L, Ashton NJ, Reinikainen M, Jakkula P, Pettila V, Hastbacka J, Tiainen M, Loisa P, Friberg H, Cronberg T, et al; COMACARE Study Group. Neurofilament light as an outcome predictor after cardiac arrest: a post hoc analysis of the COMACARE trial. *Intensive Care Med*. 2021;47:39–48. doi: 10.1007/s00134-020-06218-9
142. Wihersaari L, Reinikainen M, Furlan R, Mandelli A, Vaahersalo J, Kurola J, Tiainen M, Pettila V, Bendel S, Varpula T, et al. Neurofilament light compared to neuron-specific enolase as a predictor of unfavourable outcome after out-of-hospital cardiac arrest. *Resuscitation*. 2022;174:1–8. doi: 10.1016/j.resuscitation.2022.02.024
143. Humaloja J, Lahde M, Ashton NJ, Reinikainen M, Hastbacka J, Jakkula P, Friberg H, Cronberg T, Pettila V, Blennow K, et al; COMACARE Study Groups. GFAp and tau protein as predictors of neurological outcome after out-of-hospital cardiac arrest: a post hoc analysis of the COMACARE trial. *Resuscitation*. 2022;170:141–149. doi: 10.1016/j.resuscitation.2021.11.033
144. Hirsch K, Sandroni C, Skrifvars M, Humaloja J; ILCOR Advanced Life Support Task Force. EEG for prediction of good neurological outcome: ALS TFSR. Updated December 22, 2022. Accessed February 22, 2023. https://costr.ilcor.org/document/eeg-for-prediction-of-good-neurological-outcome-als-tfsr
145. Admiraal MM, van Rootselaar AF, Hofmeijer J, Hoedemaekers CWE, van Kaam CR, Keijzer HM, van Putten M, Schultz MJ, Horn J. Electroencephalographic reactivity as predictor of neurological outcome in postanoxic coma: a multicenter prospective cohort study. *Ann Neurol*. 2019;86:17–27. doi: 10.1002/ana.25507
146. Backman S, Cronberg T, Friberg H, Ullen S, Horn J, Kjaergaard J, Hassager C, Wanscher M, Nielsen N, Westhall E. Highly malignant routine EEG predicts poor prognosis after cardiac arrest in the Target Temperature Management trial. *Resuscitation*. 2018;131:24–28. doi: 10.1016/j.resuscitation.2018.07.024
147. Beretta S, Coppo A, Bianchi E, Zanchi C, Carone D, Stabile A, Padovano G, Sulmina E, Grassi A, Bogliun G, et al. Neurological outcome of postanoxic refractory status epilepticus after aggressive treatment. *Epilepsy Behav*. 2019;101:106374. doi: 10.1016/j.yebeh.2019.06.018
148. Carrai R, Grippo A, Scarpino M, Spalletti M, Cossu C, Lanzo G, Peris A, Cianchi G, Batacchi S, Valente S, et al. Time-dependent and independent neurophysiological indicators of prognosis in post-anoxic coma subjects treated by therapeutic hypothermia. *Minerva Anestesiol*. 2016;82:940–949.
149. Carrai R, Spalletti M, Scarpino M, Lolli F, Lanzo G, Cossu C, Bonizzoli M, Socci F, Lazzeri C, Amantini A, et al. Are neurophysiologic tests reliable, ultra-early prognostic indices after cardiac arrest? *Neurophysiol Clin*. 2021;51:133–144. doi: 10.1016/j.neucli.2021.01.005
150. Scarpino M, Lolli F, Lanzo G, Carrai R, Spalletti M, Valzania F, Lombardi M, Audenino D, Contardi S, Celani MG, et al; ProNeCA Study Group. SSEP amplitude accurately predicts both good and poor neurological outcome early after cardiac arrest; a post-hoc analysis of the ProNeCA multicentre study. *Resuscitation*. 2021;163:162–171. doi: 10.1016/j.resuscitation.2021.03.028
151. Duez CHV, Johnsen B, Ebbesen MQ, Kvaloy MB, Grejs AM, Jeppesen AN, Soreide E, Nielsen JF, Kirkegaard H. Post resuscitation prognostication by EEG in 24 vs 48 h of targeted temperature management. *Resuscitation*. 2019;135:145–152. doi: 10.1016/j.resuscitation.2018.10.035
152. Hofmeijer J, Beernink TM, Bosch FH, Beishuizen A, Tjepkema-Cloostermans MC, van Putten MJ. Early EEG contributes to multimodal outcome prediction of postanoxic coma. *Neurology*. 2015;85:137–143. doi: 10.1212/WNL.0000000000001742
153. Sondag L, Ruijter BJ, Tjepkema-Cloostermans MC, Beishuizen A, Bosch FH, van Til JA, van Putten M, Hofmeijer J. Early EEG for outcome prediction of postanoxic coma: prospective cohort study with cost-minimization analysis. *Crit Care*. 2017;21:111. doi: 10.1186/s13054-017-1693-2
154. Rossetti AO, Tovar Quiroga DF, Juan E, Novy J, White RD, Ben-Hamouda N, Britton JW, Oddo M, Rabinstein AA. Electroencephalography predicts poor and good outcomes after cardiac arrest: a two-center study. *Crit Care Med*. 2017;45:e674–e682. doi: 10.1097/CCM.0000000000002337
155. Westhall E, Rossetti AO, van Rootselaar AF, Wesenberg Kjaer T, Horn J, Ullen S, Friberg H, Nielsen N, Rosen I, Aneman A, et al; TTM-Trial Investigators. Standardized EEG interpretation accurately predicts prognosis after cardiac arrest. *Neurology*. 2016;86:1482–1490. doi: 10.1212/WNL.0000000000002462
156. Sivaraju A, Gilmore EJ, Wira CR, Stevens A, Rampal N, Moeller JJ, Greer DM, Hirsch LJ, Gaspard N. Prognostication of post-cardiac arrest coma: early clinical and electroencephalographic predictors of outcome. *Intensive Care Med*. 2015;41:1264–1272. doi: 10.1007/s00134-015-3834-x
157. Alvarez V, Reinsberger C, Scirica B, O'Brien MH, Avery KR, Henderson G, Lee JW. Continuous electrodermal activity as a potential novel neurophysiological biomarker of prognosis after cardiac arrest: a pilot study. *Resuscitation*. 2015;93:128–135. doi: 10.1016/j.resuscitation.2015.06.006
158. Lamartine Monteiro M, Taccone FS, Depondt C, Lamanna I, Gaspard N, Ligot N, Mavroudakis N, Naeije G, Vincent JL, Legros B. The prognostic value of 48-h continuous EEG during therapeutic hypothermia after cardiac arrest. *Neurocrit Care*. 2016;24:153–162. doi: 10.1007/s12028-015-0215-9
159. Leao RN, Avila P, Cavaco R, Germano N, Bento L. Therapeutic hypothermia after cardiac arrest: outcome predictors. *Rev Bras Ter Intensiva*. 2015;27:322–332. doi: 10.5935/0103-507X.20150056
160. Wennervirta JE, Ermes MJ, Tiainen SM, Salmi TK, Hynninen MS, Sarkela MO, Hynynen MJ, Stenman UH, Viertio-Oja HE, Saastamoinen KP, et al. Hypothermia-treated cardiac arrest patients with good neurological outcome differ early in quantitative variables of EEG suppression and epileptiform activity. *Crit Care Med*. 2009;37:2427–2435. doi: 10.1097/CCM.0b013e3181a0ff84
161. Oh SH, Park KN, Kim YM, Kim HJ, Youn CS, Kim SH, Choi SP, Kim SC, Shon YM. The prognostic value of continuous amplitude-integrated electroencephalogram applied immediately after return of spontaneous circulation in therapeutic hypothermia-treated cardiac arrest patients. *Resuscitation*. 2013;84:200–205. doi: 10.1016/j.resuscitation.2012.09.031
162. Rundgren M, Westhall E, Cronberg T, Rosen I, Friberg H. Continuous amplitude-integrated electroencephalogram predicts outcome in hypothermia-treated cardiac arrest patients. *Crit Care Med*. 2010;38:1838–1844. doi: 10.1097/CCM.0b013e3181eaa1e7
163. Eertmans W, Genbrugge C, Haesen J, Drieskens C, Demeestere J, Vander Laenen M, Boer W, Mesotten D, Dens J, Ernon L, et al. The

prognostic value of simplified EEG in out-of-hospital cardiac arrest patients. *Neurocrit Care*. 2019;30:139–148. doi: 10.1007/s12028-018-0587-8
164. Tjepkema-Cloostermans MC, van Meulen FB, Meinsma G, van Putten MJ. A Cerebral Recovery Index (CRI) for early prognosis in patients after cardiac arrest. *Crit Care*. 2013;17:R252. doi: 10.1186/cc13078
165. Park JH, Oh JH, Choi SP, Wee JH. Neurologic outcome after out-of-hospital cardiac arrest could be predicted with the help of bispectral-index during early targeted temperature management. *Scand J Trauma Resusc Emerg Med*. 2018;26:59. doi: 10.1186/s13049-018-0529-7
166. Seder DB, Fraser GL, Robbins T, Libby L, Riker RR. The bispectral index and suppression ratio are very early predictors of neurological outcome during therapeutic hypothermia after cardiac arrest. *Intensive Care Med*. 2010;36:281–288. doi: 10.1007/s00134-009-1691-1
167. Leary M, Fried DA, Gaieski DF, Merchant RM, Fuchs BD, Kolansky DM, Edelson DP, Abella BS. Neurologic prognostication and bispectral index monitoring after resuscitation from cardiac arrest. *Resuscitation*. 2010;81:1133–1137. doi: 10.1016/j.resuscitation.2010.04.021
168. ILCOR Advanced Life Support Adult Task Force. Short-latency somatosensory evoked potentials (SSEPs) for prediction of good neurological outcome: ALS TFSR. Updated February 1, 2023. Accessed February 22, 2023. https://costr.ilcor.org/document/short-latency-somatosensory-evoked-potentials-sseps-for-prediction-of-good-neurological-outcome-als-tfsr
169. Endisch C, Storm C, Ploner CJ, Leithner C. Amplitudes of SSEP and outcome in cardiac arrest survivors: a prospective cohort study. *Neurology*. 2015;85:1752–1760. doi: 10.1212/WNL.0000000000002123
170. Benghanem S, Nguyen LS, Gavaret M, Mira JP, Pene F, Charpentier J, Marchi A, Cariou A. SSEP N20 and P25 amplitudes predict poor and good neurologic outcomes after cardiac arrest. *Ann Intensive Care*. 2022;12:25. doi: 10.1186/s13613-022-00999-6
171. Glimmerveen AB, Keijzer HM, Ruijter BJ, Tjepkema-Cloostermans MC, van Putten M, Hofmeijer J. Relevance of somatosensory evoked potential amplitude after cardiac arrest. *Front Neurol*. 2020;11:335. doi: 10.3389/fneur.2020.00335
172. Deleted in proof.
173. Deleted in proof.
174. Holmberg MJ, Granfeldt A, Guerguerian A-M, Sandroni C, Hsu CH, Gardner RM, Lind PC, Eggertsen MA, Johannsen CM, Andersen LW. Extracorporeal cardiopulmonary resuscitation (ECPR) for cardiac arrest in pediatrics: PLS TFSR. Accessed March 7, 2023. https://costr.ilcor.org/document/extracorporeal-cardiopulmonary-resuscitation-ecpr-for-cardiac-arrest-in-pediatrics-pls-tfsr
175. Moler FW, Silverstein FS, Holubkov R, Slomine BS, Christensen JR, Nadkarni VM, Meert KL, Browning B, Pemberton VL, Page K, et al. Therapeutic hypothermia after in-hospital cardiac arrest in children. *N Engl J Med*. 2017;376:318–329. doi: 10.1056/NEJMoa1610493
176. Meert K, Telford R, Holubkov R, Slomine BS, Christensen JR, Berger J, Ofori-Amanfo G, Newth CJL, Dean JM, Moler FW. Paediatric in-hospital cardiac arrest: factors associated with survival and neurobehavioural outcome one year later. *Resuscitation*. 2018;124:96–105. doi: 10.1016/j.resuscitation.2018.01.013
177. Meert KL, Guerguerian AM, Barbaro R, Slomine BS, Christensen JR, Berger J, Topjian A, Bembea M, Tabbutt S, Fink EL, et al. Extracorporeal cardiopulmonary resuscitation: one-year survival and neurobehavioral outcome among infants and children with in-hospital cardiac arrest. *Crit Care Med*. 2019;47:393–402. doi: 10.1097/CCM.0000000000003545
178. Ichord R, Silverstein FS, Slomine BS, Telford R, Christensen J, Holubkov R, Dean JM, Moler FW; THAPCA Trial Group. Neurologic outcomes in pediatric cardiac arrest survivors enrolled in the THAPCA trials. *Neurology*. 2018;91:e123–e131. doi: 10.1212/wnl.0000000000005773
179. Mullen EM. *Mullen Scales of Early Learning*. American Guidance; 1995.
180. Wechsler D. *Wechsler Abbreviated Scale of Intelligence*: Psychological Corp; 1999.
181. Hamzah M, Othman HF, Almasri M, Al-Subu A, Lutfi R. Survival outcomes of in-hospital cardiac arrest in pediatric patients in the USA. *Eur J Pediatr*. 2021;180:2513–2520. doi: 10.1007/s00431-021-04082-3
182. Taeb M, Levin AB, Spaeder MC, Schwartz JM. Comparison of pediatric cardiopulmonary resuscitation quality in classic cardiopulmonary resuscitation and extracorporeal cardiopulmonary resuscitation events using video review. *Pediatr Crit Care Med*. 2018;19:831–838. doi: 10.1097/pcc.0000000000001644
183. Pollack MM, Holubkov R, Funai T, Clark A, Moler F, Shanley T, Meert K, Newth CJL, Carcillo J, Berger JT, et al. Relationship between the Functional Status Scale and the Pediatric Overall Performance Category and Pediatric Cerebral Performance Category Scales. *JAMA Pediatrics*. 2014;168:671. doi: 10.1001/jamapediatrics.2013.5316
184. Topjian AA, Scholefield BR, Pinto NP, Fink EL, Buysse CMP, Haywood K, Maconochie I, Nadkarni VM, de Caen A, Escalante-Kanashiro R, et al. P-COSCA (Pediatric Core Outcome Set for Cardiac Arrest) in children: an advisory statement from the International Liaison Committee on Resuscitation. *Circulation*. 2020;142:e246–e261. doi: 10.1161/cir.0000000000000911
185. Scholefield BR, Tijssen J, Ganesan SL, Kool M, Topjian A, Couto TB, Guerguerian A-M; International Liaison Committee on Resuscitation Pediatric Life Support Task Force. Clinical examination for the prediction of survival with good neurological outcome after return of circulation following pediatric cardiac arrest: PLS TFSR. Accessed March 7, 2023. https://costr.ilcor.org/document/clinical-examination-for-the-prediction-of-survival-with-good-neurological-outcome-after-return-of-circulation-following-pediatric-cardiac-arrest-pls-tfsr-1
186. Abend NS, Topjian AA, Kessler SK, Gutierrez-Colina AM, Berg RA, Nadkarni V, Dlugos DJ, Clancy RR, Ichord RN. Outcome prediction by motor and pupillary responses in children treated with therapeutic hypothermia after cardiac arrest. *Pediatric Crit Care Med*. 2012;13:32–38. doi: 10.1097/PCC.0b013e3182196a7b
187. Anton-Martin P, Moreira A, Kang P, Green ML. Outcomes of paediatric cardiac patients after 30 minutes of cardiopulmonary resuscitation prior to extracorporeal support. *Cardiol Young*. 2020;30:607–616. doi: 10.1017/S1047951120000591
188. Brooks GA, Park JT. Clinical and electroencephalographic correlates in pediatric cardiac arrest: experience at a tertiary care center. *Neuropediatrics*. 2018;49:324–329. doi: 10.1055/s-0038-1657757
189. Ducharme-Crevier L, Press CA, Kurz JE, Mills MG, Goldstein JL, Wainwright MS. Early presence of sleep spindles on electroencephalography is associated with good outcome after pediatric cardiac arrest. *Pediatr Crit Care Med*. 2017;18:452–460. doi: 10.1097/PCC.0000000000001137
190. Fink EL, Berger RP, Clark RSB, Watson RS, Angus DC, Richichi R, Panigrahy A, Callaway CW, Bell MJ, Kochanek PM. Serum biomarkers of brain injury to classify outcome after pediatric cardiac arrest. *Crit Care Med*. 2014;42:664–674. doi: 10.1097/01.ccm.0000435668.53188.80
191. Lin JJ, Hsu MH, Hsia SH, Lin YJ, Wang HS, Kuo HC, Chiang MC, Chan OW, Lee EP, Lin KL; iCNS Group. Epileptiform discharge and electrographic seizures during the hypothermia phase as predictors of rewarming seizures in children after resuscitation. *J Clin Med*. 2020;9:534. doi: 10.3390/jcm9072151
192. Topjian AA, Zhang B, Xiao R, Fung FW, Berg RA, Graham K, Abend NS. Multimodal monitoring including early EEG improves stratification of brain injury severity after pediatric cardiac arrest. *Resuscitation*. 2021;167:282–288. doi: 10.1016/j.resuscitation.2021.06.020
193. Nishisaki A, Sullivan J 3rd, Steger B, Bayer CR, Dlugos D, Lin R, Ichord R, Helfaer MA, Nadkarni V. Retrospective analysis of the prognostic value of electroencephalography patterns obtained in pediatric in-hospital cardiac arrest survivors during three years. *Pediatr Crit Care Med*. 2007;8:10–17. doi: 10.1097/01.pcc.0000256621.63135.4b 10.1097/01.pcc.0000256621.63135.4b
194. Lin YR, Wu HP, Chen WL, Wu KH, Teng TH, Yang MC, Chou CC, Chang CF, Li CJ. Predictors of survival and neurologic outcomes in children with traumatic out-of-hospital cardiac arrest during the early postresuscitative period. *J Trauma Acute Care Surg*. 2013;75:439–447. doi: 10.1097/TA.0b013e31829e2543 10.1097/TA.0b013e31829e2543
195. Scholefield BR, Tijssen J, Ganesan SL, Kool M, Topjian A, Couto TB, Guerguerian A-M; International Liaison Committee on Resuscitation Pediatric Life Support Task Force. Blood biomarkers for the prediction of good neurological outcome after return of circulation following pediatric cardiac arrest: PLS TFSR. Accessed March 7, 2023. https://costr.ilcor.org/document/blood-biomarkers-for-the-prediction-of-good-neurological-outcome-after-return-of-circulation-following-pediatric-cardiac-arrest-pls-tfsr
196. De La Llana RA, Le Marsney R, Gibbons K, Anderson B, Haisz E, Johnson K, Black A, Venugopal P, Mattke AC. Merging two hospitals: the effects on pediatric extracorporeal cardiopulmonary resuscitation outcomes. *J Pediatr Intensive Care*. 2021;10:202–209. doi: 10.1055/s-0040-1715853
197. Lopez-Herce J, del Castillo J, Matamoros M, Canadas S, Rodriguez-Calvo A, Cecchetti C, Rodriguez-Nunez A, Carrillo A; Iberoamerican Pediatric Cardiac Arrest Study Network RIBEPCI. Post return of spontaneous circulation factors associated with mortality in pediatric in-hospital cardiac arrest: a prospective multicenter multinational observational study. *Crit Care*. 2014;18:607. doi: 10.1186/s13054-014-0607-9
198. Meert K, Slomine BS, Silverstein FS, Christensen J, Ichord R, Telford R, Holubkov R, Dean JM, Moler FW. One-year cognitive and neurologic

outcomes in survivors of paediatric extracorporeal cardiopulmonary resuscitation. *Resuscitation*. 2019;139:299–307. doi: http://dx.doi.org/10.1016/j.resuscitation.2019.02.023
199. Moler FW, Silverstein FS, Holubkov R, Slomine BS, Christensen JR, Nadkarni VM, Meert KL, Clark AE, Browning B, Pemberton VL, et al. Therapeutic hypothermia after out-of-hospital cardiac arrest in children. *N Engl J Med*. 2015;372:1898–1908. doi: 10.1056/NEJMoa1411480
200. Fink EL, Kochanek PM, Panigrahy A, Beers SR, Berger RP, Bayir H, Pineda J, Newth C, Topjian AA, Press CA, et al. Association of blood-based brain injury biomarker concentrations with outcomes after pediatric cardiac arrest. *JAMA Netw Open*. 2022;5:e2230518. doi: 10.1001/jamanetworkopen.2022.30518
201. Fink EL, Berger RP, Clark RSB, Watson RS, Angus DC, Panigrahy A, Richichi R, Callaway CW, Bell MJ, Mondello S, et al. Exploratory study of serum ubiquitin carboxyl-terminal esterase L1 and glial fibrillary acidic protein for outcome prognostication after pediatric cardiac arrest. *Resuscitation*. 2016;101:65–70. doi: 10.1016/j.resuscitation.2016.01.024
202. Kirschen MP, Yehya N, Graham K, Kilbaugh T, Berg RA, Topjian A, Diaz-Arrastia R. Circulating neurofilament light chain is associated with survival after pediatric cardiac arrest. *Pediatr Crit Care Med*. 2020;21:656–661. doi: 10.1097/pcc.0000000000002294
203. Bangshoj J, Liebetrau B, Wiberg S, Gjedsted J, Kjaergaard J, Hassager C, Wanscher M. The value of the biomarkers neuron-specific enolase and s100 calcium-binding protein for prediction of mortality in children resuscitated after cardiac arrest. *Pediatr Cardiol*. 2022;43:1659–1665. doi: 10.1007/s00246-022-02899-9
204. Scholefield BR, Tijssen J, Ganesan SL, Kool M, Topjian A, Couto TB, Guerguerian A-M; International Liaison Committee on Resuscitation Pediatric Life Support Task Force. Electrophysiology testing for the prediction of survival with good neurological outcome after return of circulation following pediatric cardiac arrest: PLS TFSR. Accessed March 7, 2023. https://costr.ilcor.org/document/electrophysiology-testing-for-the-prediction-of-survival-with-good-neurological-outcome-after-return-of-circulation-following-pediatric-cardiac-arrest-pls-tfsr
205. Fung FW, Topjian AA, Xiao R, Abend NS. Early EEG features for outcome prediction after cardiac arrest in children. *J Clin Neurophysiol*. 2019;36:349–357. doi: 10.1097/WNP.0000000000000591
206. Kirschen MP, Licht DJ, Faerber J, Mondal A, Graham K, Winters M, Balu R, Diaz-Arrastia R, Berg RA, Topjian A, et al. Association of MRI brain injury with outcome after pediatric out-of-hospital cardiac arrest. *Neurology*. 2021;96:e719–e731. doi: 10.1212/WNL.0000000000011217
207. Lin JJ, Lin YJ, Hsia SH, Kuo HC, Wang HS, Hsu MH, Chiang MC, Lin CY, Lin KL. Early clinical predictors of neurological outcome in children with asphyxial out-of-hospital cardiac arrest treated with therapeutic hypothermia. *Front Pediatr*. 2019;7:534. doi: 10.3389/fped.2019.00534
208. Ostendorf AP, Hartman ME, Friess SH. Early electroencephalographic findings correlate with neurologic outcome in children following cardiac arrest. *Pediatr Crit Care Med*. 2016;17:667–676. doi: 10.1097/PCC.0000000000000791
209. Topjian AA, Sanchez SM, Shults J, Berg RA, Dlugos DJ, Abend NS. Early electroencephalographic background features predict outcomes in children resuscitated from cardiac arrest. *Pediatr Crit Care Med*. 2016;17:547–557. doi: 10.1097/PCC.0000000000000740
210. Yang D, Ryoo E, Kim HJ. Combination of early EEG, brain CT, and ammonia level is useful to predict neurologic outcome in children resuscitated from cardiac arrest. *Front Pediatr*. 2019;7:223. doi: 10.3389/fped.2019.00223
211. McDevitt WM, Rowberry TA, Davies P, Bill PR, Notghi LM, Morris KP, Scholefield BR. The prognostic value of somatosensory evoked potentials in children after cardiac arrest: the SEPIA study. *J Clin Neurophysiol*. 2021;38:30–35. doi: 10.1097/wnp.0000000000000649
212. Kessler SK, Topjian AA, Gutierrez-Colina AM, Ichord RN, Donnelly M, Nadkarni VM, Berg RA, Dlugos DJ, Clancy RR, Abend NS. Short-term outcome prediction by electroencephalographic features in children treated with therapeutic hypothermia after cardiac arrest. *Neurocrit Care*. 2011;14:37–43. doi: 10.1007/s12028-010-9450-2
213. Bourgoin P, Barrault V, Joram N, Leclair Visonneau L, Toulgoat F, Anthoine E, Loron G, Chenouard A. The prognostic value of early amplitude-integrated electroencephalography monitoring after pediatric cardiac arrest. *Pediatr Crit Care Med*. 2020;248:255. doi: 10.1097/PCC.0000000000002171
214. Scholefield BR, Tijssen J, Ganesan SL, Kool M, Topjian A, Couto TB, Guerguerian A-M; International Liaison Committee on Resuscitation Pediatric Life Support Task Force. Brain imaging for the prediction of survival with good neurological outcome after return of circulation following pediatric cardiac arrest: PLS TFSR. Accessed March 7, 2023. https://costr.ilcor.org/document/brain-imaging-for-the-prediction-of-survival-with-good-neurological-outcome-after-return-of-circulation-following-pediatric-cardiac-arrest-pls-tfsr
215. Starling RM, Shekdar K, Licht D, Nadkarni VM, Berg RA, Topjian AA. Early head CT findings are associated with outcomes after pediatric out-of-hospital cardiac arrest. *Pediatr Crit Care Med*. 2015;16:542–548. doi: 10.1097/PCC.0000000000000404
216. Yang D, Ha SG, Ryoo E, Choi JY, Kim HJ. Multimodal assessment using early brain CT and blood pH improve prediction of neurologic outcomes after pediatric cardiac arrest. *Resuscitation*. 2019;137:7–13. doi: 10.1016/j.resuscitation.2019.01.033
217. Fink EL, Panigrahy A, Clark RSB, Fitz CR, Sittel D, Kochanek PM, Zuccoli G. Regional brain injury on conventional and diffusion weighted MRI is associated with outcome after pediatric cardiac arrest. *Neurocrit Care*. 2013;19:31–40. doi: 10.1007/s12028-012-9706-0
218. Fink EL, Wisnowski J, Clark R, Berger RP, Fabio A, Furtado A, Narayan S, Angus DC, Watson RS, Wang C, et al. Brain MR imaging and spectroscopy for outcome prognostication after pediatric cardiac arrest. *Resuscitation*. 2020;157:185–194. doi: 10.1016/j.resuscitation.2020.06.033
219. Yacoub M, Birchansky B, Mlynash M, Berg M, Knight L, Hirsch KG, Su F; Revive Initiative at Stanford Children's Hospital. The prognostic value of quantitative diffusion-weighted MRI after pediatric cardiopulmonary arrest. *Resuscitation*. 2019;135:103–109. doi: 10.1016/j.resuscitation.2018.11.003
220. Lin JJ, Hsia SH, Wang HS, Chiang MC, Lin KL. Transcranial Doppler ultrasound in therapeutic hypothermia for children after resuscitation. *Resuscitation*. 2015;89:182–187. doi: 10.1016/j.resuscitation.2015.01.029
221. Perlman JM, Wyllie J, Kattwinkel J, Wyckoff MH, Aziz K, Guinsburg R, Kim HS, Liley HG, Mildenhall L, Simon WM, et al. Part 7: neonatal resuscitation: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2015;132:S204–S241. doi: 10.1161/cir.0000000000000276
222. de Almeida MF, Guinsburg R, Sancho GA, Rosa IR, Lamy ZC, Martinez FE, da Silva RP, Ferrari LS, de Souza Rugolo LM, Abdallah VO, et al. Hypothermia and early neonatal mortality in preterm infants. *J Pediatr*. 2014;164:271–275.e1. doi: 10.1016/j.jpeds.2013.09.049
223. Wilson E, Maier RF, Norman M, Misselwitz B, Howell EA, Zeitlin J, Bonamy AK; Effective Perinatal Intensive Care in Europe Research Group. Admission hypothermia in very preterm infants and neonatal mortality and morbidity. *J Pediatr*. 2016;175:61–67 e64. doi: 10.1016/j.jpeds.2016.04.016
224. Lunze K, Bloom DE, Jamison DT, Hamer DH. The global burden of neonatal hypothermia: systematic review of a major challenge for newborn survival. *BMC Med*. 2013;11:24. doi: 10.1186/1741-7015-11-24
225. Dawson JA, Ramaswamy VV, de Almeida MF, Trang J, Trevisanuto D, Nakwa F, Kamlin C, Weiner G, Wyckoff MH, Liley HG; International Liaison Committee on Resuscitation Neonatal Life Support Task Force. Maintaining normal temperature immediately after birth in preterm infants: NLS 5101 TF SR. Accessed February 17, 2023. https://costr.ilcor.org/document/maintaining-normal-temperature-immediately-after-birth-in-preterm-infants-nls-5101-tf-sr
226. World Health Organization. Thermal protection of the newborn: a practical guide. 1997. Accessed February 8, 2021. https://apps.who.int/iris/bitstream/handle/10665/63986/WHO_RHT_MSM_97.2.pdf
227. Ahmed BT, Hussein MA, Monir H. Effect of plastic bag (vinyl bags) on prevention of hypothermia in preterm infants. *Med J Cairo Univ*. 2013;81:169–173.
228. Bhavsar S, Kabra N, Avasthi B, Sharma S, Dash S, Tali S, Padhi P, Ahmed J. Efficacy and safety of polythene wrap in preventing hypothermia in preterm and low birth weight neonates during transport: a randomized controlled trial. *Perinatology*. 2015;16:23–30.
229. Chantaroj S, Techasatid W. Effect of polyethylene bag to prevent heat loss in preterm infants at birth: a randomized controlled trial. *J Med Assoc Thai*. 2011;94:S32–S37.
230. Chawla S, Amaram A, Gopal SP, Natarajan G. Safety and efficacy of Transwarmer mattress for preterm neonates: results of a randomized controlled trial. *J Perinatol*. 2011;31:780–784. doi: 10.1038/jp.2011.33
231. Farhadi R, Naderi M, Rahmani Z, Ghaffari V, Khalilian A. Effect of "ZIPKIF" plastic bag on prevention of hypothermia in preterm infants: a randomized controlled trial. *J Mazandaran Univ Med Sci*. 2012;22:19–26.
232. Ibrahim CP, Yoxall CW. Use of self-heating gel mattresses eliminates admission hypothermia in infants born below 28 weeks gestation. *Eur J Pediatr*. 2010;169:795–799. doi: 10.1007/s00431-009-1113-y
233. Knobel RB, Wimmer JE Jr, Holbert D. Heat loss prevention for preterm infants in the delivery room. *J Perinatol*. 2005;25:304–308. doi: 10.1038/sj.jp.7211289

234. Lewis DA, Sanders LP, Brockopp DY. The effect of three nursing interventions on thermoregulation in low birth weight infants. *Neonatal Netw*. 2011;30:160–164. doi: 10.1891/0730-0832.30.3.160
235. Mathew B, Lakshminrusimha S, Sengupta S, Carrion V. Randomized controlled trial of vinyl bags versus thermal mattress to prevent hypothermia in extremely low-gestational-age infants. *Am J Perinatol*. 2013;30:317–322. doi: 10.1055/s-0032-1324700
236. McCarthy LK, Molloy EJ, Twomey AR, Murphy JF, O'Donnell CP. A randomized trial of exothermic mattresses for preterm newborns in polyethylene bags. *Pediatrics*. 2013;132:e135–e141. doi: 10.1542/peds.2013-0279
237. McCarthy LK, O'Donnell CP. Warming preterm infants in the delivery room: polyethylene bags, exothermic mattresses or both? *Acta Paediatr*. 2011;100:1534–1537. doi: 10.1111/j.1651-2227.2011.02375.x
238. McGrory L, Owen LS, Thio M, Dawson JA, Rafferty AR, Malhotra A, Davis PG, Kamlin COF. A randomized trial of conditioned or unconditioned gases for stabilizing preterm infants at birth. *J Pediatr*. 2018;193:47–53. doi: 10.1016/j.jpeds.2017.09.006
239. Meyer MP, Hou D, Ishrar NN, Dito I, te Pas AB. Initial respiratory support with cold, dry gas versus heated humidified gas and admission temperature of preterm infants. *J Pediatr*. 2015;166:245–250.e241. doi: 10.1016/j.jpeds.2014.09.049
240. Pinheiro JM, Boynton S, Furdon SA, Dugan R, Reu-Donlon C. Use of chemical warming packs during delivery room resuscitation is associated with decreased rates of hypothermia in very low-birth-weight neonates. *Adv Neonatal Care*. 2011;11:357–362. doi: 10.1097/ANC.0b013e318229aa8f
241. Reilly MC, Vohra S, Rac VE, Dunn M, Ferrelli K, Kiss A, Vincer M, Wimmer J, Zayack D, Soll RF; Vermont Oxford Network Heat Loss Prevention (HeLP) Trial Study Group Randomized trial of occlusive wrap for heat loss prevention in preterm infants. *J Pediatr*. 2015;166:262–268.e2. doi: 10.1016/j.jpeds.2014.09.068
242. Reilly MC, Vohra S, Rac VE, Zayack D, Wimmer J, Vincer M, Ferrelli K, Kiss A, Soll RF, Dunn M. Parallel exploratory RCT of polyethylene wrap for heat loss prevention in infants born at less than 24 weeks' gestation. *Neonatology*. 2019;116:37–41. doi: 10.1159/000497253
243. Simon P, Dannaway D, Bright B, Krous L, Wlodaver A, Burks B, Thi C, Milam J, Escobedo M. Thermal defense of extremely low gestational age newborns during resuscitation: exothermic mattresses vs polyethylene wrap. *J Perinatol*. 2011;31:33–37. doi: 10.1038/jp.2010.56
244. Singh A, Duckett J, Newton T, Watkinson M. Improving neonatal unit admission temperatures in preterm babies: exothermic mattresses, polythene bags or a traditional approach? *J Perinatol*. 2010;30:45–49. doi: 10.1038/jp.2009.94
245. Smith J, Usher K, Alcock G, Buettner P. Application of plastic wrap to improve temperatures in infants born less than 30 weeks gestation: a randomized controlled trial. *Neonatal Netw*. 2013;32:235–245. doi: 10.1891/0730-0832.32.4.235
246. te Pas AB, Lopriore E, Dito I, Morley CJ, Walther FJ. Humidified and heated air during stabilization at birth improves temperature in preterm infants. *Pediatrics*. 2010;125:e1427–e1432. doi: 10.1542/peds.2009-2656
247. Trevisanuto D, Doglioni N, Cavallin F, Parotto M, Micaglio M, Zanardo V. Heat loss prevention in very preterm infants in delivery rooms: a prospective, randomized, controlled trial of polyethylene caps. *J Pediatr*. 2010;156:914–917.e1. doi: 10.1016/j.jpeds.2009.12.021
248. Vohra S, Frent G, Campbell V, Abbott M, Whyte R. Effect of polyethylene occlusive skin wrapping on heat loss in very low birth weight infants at delivery: a randomized trial. *J Pediatr*. 1999;134:547–551. doi: 10.1016/s0022-3476(99)70238-6
249. Vohra S, Roberts RS, Zhang B, Janes M, Schmidt B. Heat Loss Prevention (HeLP) in the delivery room: a randomized controlled trial of polyethylene occlusive skin wrapping in very preterm infants. *J Pediatr*. 2004;145:750–753. doi: 10.1016/j.jpeds.2004.07.036
250. Duryea EL, Nelson DB, Wyckoff MH, Grant EN, Tao W, Sadana N, Chalak LF, McIntire DD, Leveno KJ. The impact of ambient operating room temperature on neonatal and maternal hypothermia and associated morbidities: a randomized controlled trial. *Am J Obstet Gynecol*. 2016;214:505.e1–505.e7. doi: 10.1016/j.ajog.2016.01.190
251. Jia YS, Lin ZL, Lv H, Li YM, Green R, Lin J. Effect of delivery room temperature on the admission temperature of premature infants: a randomized controlled trial. *J Perinatol*. 2013;33:264–267. doi: 10.1038/jp.2012.100
252. Johannsen JKI, Vochem M, Neuberger P. Does a higher ambient temperature in the delivery room prevent hypothermia in preterm infants <1500 g? [in German]. *Z Geburtshilfe Neonatol*. 2017;221:235–240. doi: 10.1055/s-0043-118809
253. Kent AL, Williams J. Increasing ambient operating theatre temperature and wrapping in polyethylene improves admission temperature in premature infants. *J Paediatr Child Health*. 2008;44:325–331. doi: 10.1111/j.1440-1754.2007.01264.x
254. Gathwala G, Singh G, Kunal, Agrawal N. Safety and efficacy of vinyl bags in prevention of hypothermia of preterm neonates at birth. *Indian J Public Health*. 2010;54:24–26. doi: 10.4103/0019-557X.70543
255. Nimbalkar SM, Khanna AK, Patel DV, Nimbalkar AS, Phatak AG. Efficacy of polyethylene skin wrapping in preventing hypothermia in preterm neonates (<34 weeks): a parallel group non-blinded randomized control trial. *J Trop Pediatr*. 2019;65:122–129. doi: 10.1093/tropej/fmy025
256. Rohana J, Khairina W, Boo NY, Shareena I. Reducing hypothermia in preterm infants with polyethylene wrap. *Pediatr Int*. 2011;53:468–474. doi: 10.1111/j.1442-200X.2010.03295.x
257. Talakoub S, Shahbazifard Z, Armanian AM, Ghazavi Z. Effect of two polyethylene covers in prevention of hypothermia among premature neonates. *Iran J Nurs Midwifery Res*. 2015;20:322–326.
258. Cavallin F, Doglioni N, Allodi A, Battajon N, Vedovato S, Capasso L, Gitto E, Laforgia N, Paviotti G, Capretti MG, et al. Thermal management with and without servo-controlled system in preterm infants immediately after birth: a multicentre, randomised controlled study. *Arch Dis Child Fetal Neonatal Ed*. 2021;106:572–577. doi: 10.1136/archdischild-2020-320567
259. Bergman NJ, Linley LL, Fawcus SR. Randomized controlled trial of skin-to-skin contact from birth versus conventional incubator for physiological stabilization in 1200- to 2199-gram newborns. *Acta Paediatr*. 2004;93:779–785. doi: 10.1111/j.1651-2227.2004.tb03018.x
260. Linnér A, Klemming S, Sundberg B, Lilliesköld S, Westrup B, Jonas W, Skiöld B. Immediate skin-to-skin contact is feasible for very preterm infants but thermal control remains a challenge. *Acta Paediatr*. 2020;109:697–704. doi: 10.1111/apa.15062
261. Ramaswamy VV, de Almeida MF, Dawson JA, Trevisanuto D, Nakwa FL, Kamlin CO, Hosono S, Wyckoff MH, Liley HG; International Liaison Committee on Resuscitation Neonatal Life Support Task F. Maintaining normal temperature immediately after birth in late preterm and term infants: a systematic review and meta-analysis. *Resuscitation*. 2022;180:81–98. doi: 10.1016/j.resuscitation.2022.09.014
262. Arya S, Naburi H, Kawaza K, Newton S, Anyabolu CH, Bergman N, Rao SPN, Mittal P, Assenga E, Gadama L, et al. Immediate "kangaroo mother care" and survival of infants with low birth weight. *N Engl J Med*. 2021;384:2028–2038. doi: 10.1056/NEJMoa2026486
263. Perlman JM, Wyllie J, Kattwinkel J, Atkins DL, Chameides L, Goldsmith JP, Guinsburg R, Hazinski MF, Morley C, Richmond S, et al. Part 11: Neonatal resuscitation: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2010;122:S516–S538. doi: 10.1161/circulationaha.110.971127
264. Wyckoff MH, Wyllie J, Aziz K, de Almeida MF, Fabres J, Fawke J, Guinsburg R, Hosono S, Isayama T, Kapadia VS, et al; Neonatal Life Support Collaborators. Neonatal life support: 2020 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Circulation*. 2020;142(suppl 1):S185–S221. doi: 10.1161/CIR.0000000000000895
265. Kawakami MD, Kapadia VS, Strand M, Gately C, Costa-Nobre DT, Davis PG, de Almeida MF, El-Naggar W, Fabres JG, Fawke J, et al; International Liaison Committee on Resuscitation (ILCOR) Neonatal Life Support Task Force. Heart rate assessment methods in delivery room—diagnostic characteristics: NLS 5200 TF SR. Accessed February 17, 2023. https://costr.ilcor.org/document/heart-rate-assessment-methods-in-delivery-room-diagnostic-characteristics-nls-5200-tf-sr
266. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet*. 1986;1:307–310.
267. Bland JM, Altman DG. Comparing methods of measurement: why plotting difference against standard method is misleading. *Lancet*. 1995;346:1085–1087. doi: 10.1016/s0140-6736(95)91748-9
268. Bland JM, Altman DG. Measuring agreement in method comparison studies. *Stat Methods Med Res*. 1999;8:135–160. doi: 10.1177/096228029900800204
269. Giavarina D. Understanding Bland Altman analysis. *Biochem Med (Zagreb)*. 2015;25:141–151. doi: 10.11613/bm.2015.015
270. Montenij LJ, Buhre WF, Jansen JR, Kruitwagen CL, de Waal EE. Methodology of method comparison studies evaluating the validity of cardiac output monitors: a stepwise approach and checklist. *Br J Anaesth*. 2016;116:750–758. doi: 10.1093/bja/aew094
271. Abbey NV, Mashruwala V, Weydig HM, Steven Brown L, Ramon EL, Ibrahim J, Mir IN, Wyckoff MH, Kapadia V. Electrocardiogram for heart rate evaluation during preterm resuscitation at birth: a randomized trial. *Pediatr Res*. 2022;91:1445–1451. doi: 10.1038/s41390-021-01731-z

272. Murphy MC, De Angelis L, McCarthy LK, O'Donnell CPF. Randomised study comparing heart rate measurement in newly born infants using a monitor incorporating electrocardiogram and pulse oximeter versus pulse oximeter alone. *Arch Dis Child Fetal Neonatal Ed*. 2019;104:F547–F550. doi: 10.1136/archdischild-2017-314366
273. Murphy MC, Jenkinson A, Coveney J, McCarthy LK, O'Donnell CPF. Randomised study of heart rate measurement in preterm newborns with ECG plus pulse oximetry versus oximetry alone. *Arch Dis Child Fetal Neonatal Ed*. 2021;106:438–441. doi: 10.1136/archdischild-2020-320892
274. Bjorland PA, Ersdal HL, Øymar K, Rettedal SI. Compliance with guidelines and efficacy of heart rate monitoring during newborn resuscitation: a prospective video study. *Neonatology*. 2020;117:175–181. doi: 10.1159/000506772
275. Bobillo-Perez S, Balaguer M, Jordan I, Batista-Muñoz A, Ramon M, Otero O, Sorribes C, Rodriguez-Fanjul J. Delivery room ultrasound study to assess heart rate in newborns: DELIROUS study. *Eur J Pediatr*. 2021;180:783–790. doi: 10.1007/s00431-020-03776-4
276. Bush JB, Cooley V, Perlman J, Chang C. NeoBeat offers rapid newborn heart rate assessment. *Arch Dis Child Fetal Neonatal Ed*. 2021;106:550–552. doi: 10.1136/archdischild-2020-320901
277. Dawson JA, Saraswat A, Simionato L, Thio M, Kamlin CO, Owen LS, Schmölzer GM, Davis PG. Comparison of heart rate and oxygen saturation measurements from Masimo and Nellcor pulse oximeters in newly born term infants. *Acta Paediatr*. 2013;102:955–960. doi: 10.1111/apa.12329
278. Henry C, Shipley L, Ward C, Mirahmadi S, Liu C, Morgan S, Crowe J, Carpenter J, Hayes-Gill B, Sharkey D. Accurate neonatal heart rate monitoring using a new wireless, cap mounted device. *Acta Paediatr*. 2021;110:72–78. doi: 10.1111/apa.15303
279. Iglesias B, Rodríguez MJ, Aleo E, Criado E, Martí Nez-Orgado J, Arruza L. 3-Lead electrocardiogram is more reliable than pulse oximetry to detect bradycardia during stabilisation at birth of very preterm infants. *Arch Dis Child Fetal Neonatal Ed*. 2018;103:F233–F237. doi: 10.1136/archdischild-2016-311492
280. Iglesias B, Rodríguez MJ, Aleo E, Criado E, Herranz G, Moro M, Martínez Orgado J, Arruza L. Pulse oximetry versus electrocardiogram for heart rate assessment during resuscitation of the preterm infant [in Spanish]. *An Pediatr (Barc)*. 2016;84:271–277. doi: 10.1016/j.anpedi.2015.08.012
281. Kamlin CO, Dawson JA, O'Donnell CP, Morley CJ, Donath SM, Sekhon J, Davis PG. Accuracy of pulse oximetry measurement of heart rate of newborn infants in the delivery room. *J Pediatr*. 2008;152:756–760. doi: 10.1016/j.jpeds.2008.01.002
282. Katheria A, Rich W, Finer N. Electrocardiogram provides a continuous heart rate faster than oximetry during neonatal resuscitation. *Pediatrics*. 2012;130:e1177–e1181. doi: 10.1542/peds.2012-0784
283. Mizumoto H, Tomotaki S, Shibata H, Ueda K, Akashi R, Uchio H, Hata D. Electrocardiogram shows reliable heart rates much earlier than pulse oximetry during neonatal resuscitation. *Pediatr Int*. 2012;54:205–207. doi: 10.1111/j.1442-200X.2011.03506.x
284. van Vonderen JJ, Hooper SB, Kroese JK, Roest AA, Narayen IC, van Zwet EW, te Pas AB. Pulse oximetry measures a lower heart rate at birth compared with electrocardiography. *J Pediatr*. 2015;166:49–53. doi: 10.1016/j.jpeds.2014.09.015
285. Kamlin CO, O'Donnell CP, Everest NJ, Davis PG, Morley CJ. Accuracy of clinical assessment of infant heart rate in the delivery room. *Resuscitation*. 2006;71:319–321. doi: 10.1016/j.resuscitation.2006.04.015
286. Cavallin F, Cori MS, Negash S, Azzimonti G, Vento G, Putoto G, Trevisanuto D. Heart rate determination in newborns at risk for resuscitation in a low-resource setting: a randomized controlled trial. *J Pediatr*. 2020;221:88–92.e1. doi: 10.1016/j.jpeds.2020.02.026
287. Murphy MC, De Angelis L, McCarthy LK, O'Donnell CPF. Comparison of infant heart rate assessment by auscultation, ECG and oximetry in the delivery room. *Arch Dis Child Fetal Neonatal Ed*. 2018;103:F490–F492. doi: 10.1136/archdischild-2017-314367
288. Treston BP, Semberova J, Kernan R, Crothers E, Branagan A, O'Cathain N, Miletin J. Assessment of neonatal heart rate immediately after birth using digital stethoscope, handheld ultrasound and electrocardiography: an observational cohort study. *Arch Dis Child Fetal Neonatal Ed*. 2019;104:F227. doi: 10.1136/archdischild-2018-315619
289. Solevåg AL, Monnelly VJ, Josephsen JB, Isayama T, de Almeida MF, Guinsburg R, Costa-Nobre DT, Davis PG, El-Naggar W, Fabres JG, et al; International Liaison Committee on Resuscitation Neonatal Life Support Task Force. Exhaled CO_2 to guide non-invasive ventilation at birth: NLS 5350; TFSR. Accessed February 17, 2023. https://costr.ilcor.org/document/exhaled-co2-to-guide-non-invasive-ventilation-at-birth-nls-5350-tfsr
290. Blank D, Rich W, Leone T, Garey D, Finer N. Pedi-cap color change precedes a significant increase in heart rate during neonatal resuscitation. *Resuscitation*. 2014;85:1568–1572. doi: 10.1016/j.resuscitation.2014.08.027
291. Blank DA, Badurdeen S, Omar FKC, Jacobs SE, Thio M, Dawson JA, Kane SC, Dennis AT, Polglase GR, Hooper SB, et al. Baby-directed umbilical cord clamping: a feasibility study. *Resuscitation*. 2018;131:1–7. doi: 10.1016/j.resuscitation.2018.07.020
292. Finer NN, Rich W, Wang C, Leone T. Airway obstruction during mask ventilation of very low birth weight infants during neonatal resuscitation. *Pediatrics*. 2009;123:865–869. doi: 10.1542/peds.2008-0560
293. Hawkes GA, Finn D, Kenosi M, Livingstone V, O'Toole JM, Boylan GB, O'Halloran KD, Ryan AC, Dempsey EM. A randomized controlled trial of end-tidal carbon dioxide detection of preterm infants in the delivery room. *J Pediatr*. 2017;182:74–78.e2. doi: 10.1016/j.jpeds.2016.11.006
294. Kang LJ, Cheung PY, Pichler G, O'Reilly M, Aziz K, Schmölzer GM. Monitoring lung aeration during respiratory support in preterm infants at birth. *PLoS One*. 2014;9:e102729. doi: 10.1371/journal.pone.0102729
295. Kong JY, Rich W, Finer NN, Leone TA. Quantitative end-tidal carbon dioxide monitoring in the delivery room: a randomized controlled trial. *J Pediatr*. 2013;163:104–108.e1. doi: 10.1016/j.jpeds.2012.12.016
296. Mizumoto H, Iki Y, Yamashita S, Hata D. Expiratory CO_2 as the first sign of successful ventilation during neonatal resuscitation. *Pediatr Int*. 2015;57:186–188. doi: 10.1111/ped.12553
297. Ngan AY, Cheung PY, Hudson-Mason A, O'Reilly M, van Os S, Kumar M, Aziz K, Schmölzer GM. Using exhaled CO(2) to guide initial respiratory support at birth: a randomised controlled trial. *Arch Dis Child Fetal Neonatal Ed*. 2017;102:F525–F531. doi: 10.1136/archdischild-2016-312286
298. Muir JD, Randalls PB, Smith GB. End tidal carbon dioxide detector for monitoring cardiopulmonary resuscitation. *BMJ*. 1990;301:41–42. doi: 10.1136/bmj.301.6742.41-b
299. Kattwinkel J, Niermeyer S, Nadkarni V, Tibballs J, Phillips B, Zideman D, Van Reempts P, Osmond M. Resuscitation of the newly born infant: an advisory statement from the Pediatric Working Group of the International Liaison Committee on Resuscitation. *Eur J Pediatr*. 1999;158:345–358. doi: 10.1007/s004310051090
300. Ramachandran S, Bruckner M, Wyckoff MH, Schmölzer GM. Chest compressions in newborn infants: a scoping review [published online December 1 2022]. *Arch Dis Child Fetal Neonatal Ed*. doi: 10.1136/archdischild-2022-324529. https://fn.bmj.com/content/early/2022/12/01/archdischild-2022-324529.long
301. Ramachandran S, Bruckner M, Wyckoff MH, Smölzer GM; International Liaison Committee on Resuscitation Neonatal Life Support Task Force. Heart rate for starting neonatal chest compressions: NLS 5500 TF ScR. Accessed February 17, 2023. https://costr.ilcor.org/document/nls-5500-heart-rate-for-starting-neonatal-chest-compressions-tfscr
302. Agrawal V, Lakshminrusimha S, Chandrasekharan P. Chest compressions for bradycardia during neonatal resuscitation: do we have evidence? *Children (Basel)*. 2019;6:119. doi: 10.3390/children6110119
303. Ramachandran S, Bruckner M, Wyckoff MH, Schmölzer GM; International Liaison Committee on Resuscitation Neonatal Life Support Task Force. Supplemental oxygen during chest compressions: NLS 5503 ScR. Accessed February 17, 2023. https://costr.ilcor.org/document/supplemental-oxygen-during-chest-compressions-nls-5503-scr
304. Dannevig I, Solevåg AL, Saugstad OD, Nakstad B. Lung injury in asphyxiated newborn pigs resuscitated from cardiac arrest: the impact of supplementary oxygen, longer ventilation intervals and chest compressions at different compression-to-ventilation ratios. *Open Respir Med J*. 2012;6:89–96. doi: 10.2174/1874306401206010089
305. Dannevig I, Solevåg AL, Sonerud T, Saugstad OD, Nakstad B. Brain inflammation induced by severe asphyxia in newborn pigs and the impact of alternative resuscitation strategies on the newborn central nervous system. *Pediatr Res*. 2013;73:163–170. doi: 10.1038/pr.2012.167
306. Linner R, Werner O, Perez-de-Sa V, Cunha-Goncalves D. Circulatory recovery is as fast with air ventilation as with 100% oxygen after asphyxia-induced cardiac arrest in piglets. *Pediatr Res*. 2009;66:391–394. doi: 10.1203/PDR.0b013e3181b3b110
307. Solevåg AL, Dannevig I, Nakstad B, Saugstad OD. Resuscitation of severely asphyctic newborn pigs with cardiac arrest by using 21% or 100% oxygen. *Neonatology*. 2010;98:64–72. doi: 10.1159/000275560
308. Solevåg AL, Garcia-Hidalgo C, Cheung PY, Lee TF, O'Reilly M, Schmölzer GM. Ventilation with 18, 21, or 100% oxygen during cardiopulmonary resuscitation of asphyxiated piglets: a randomized controlled animal trial. *Neonatology*. 2020;117:102–110. doi: 10.1159/000504494

309. Solevåg AL, Schmölzer GM, O'Reilly M, Lu M, Lee TF, Hornberger LK, Nakstad B, Cheung PY. Myocardial perfusion and oxidative stress after 21% vs. 100% oxygen ventilation and uninterrupted chest compressions in severely asphyxiated piglets. *Resuscitation*. 2016;106:7–13. doi: 10.1016/j.resuscitation.2016.06.014
310. Ramachandran S, Bruckner M, Wyckoff MH, Schmölzer GM; International Liaison Committee on Resuscitation Neonatal Life Support Task Force. Neonatal chest compression technique (other techniques versus two thumb): NLS 5501 TF ScR. Accessed February 17, 2023. https://costr.ilcor.org/document/nls-5501-neonatal-chest-compression-technique-other-techniques-versus-two-thumb-nls-tf-scr
311. Cheung PY, Huang H, Xu C, Liu JQ, Ting JY, Wong R, Lee W, Xue Y, Yi Y. Comparing the quality of cardiopulmonary resuscitation performed at the over-the-head position and lateral position of neonatal manikin. *Front Pediatr*. 2019;7:559. doi: 10.3389/fped.2019.00559
312. Christman C, Hemway RJ, Wyckoff MH, Perlman JM. The two-thumb is superior to the two-finger method for administering chest compressions in a manikin model of neonatal resuscitation. *Arch Dis Child Fetal Neonatal Ed*. 2011;96:F99–F101. doi: 10.1136/adc.2009.180406
313. Dorfsman ML, Menegazzi JJ, Wadas RJ, Auble TE. Two-thumb vs. two-finger chest compression in an infant model of prolonged cardiopulmonary resuscitation. *Acad Emerg Med*. 2000;7:1077–1082. doi: 10.1111/j.1553-2712.2000.tb01255.x
314. Fakhraddin BZ, Shimizu N, Kurosawa S, Sakai H, Miyasaka K, Mizutani S. New method of chest compression for infants in a single rescuer situation: thumb-index finger technique. *J Med Dent Sci*. 2011;58:15–22.
315. Huynh TK, Hemway RJ, Perlman JM. The two-thumb technique using an elevated surface is preferable for teaching infant cardiopulmonary resuscitation. *J Pediatr*. 2012;161:658–661. doi: 10.1016/j.jpeds.2012.03.019
316. Jang HY, Wolfe H, Hsieh TC, Abbadessa MK, Myers S, Nadkarni V, Donoghue A. Infant chest compression quality: a video-based comparison of two-thumb versus one-hand technique in the emergency department. *Resuscitation*. 2018;122:36–40. doi: 10.1016/j.resuscitation.2017.11.044
317. Jiang J, Zou Y, Shi W, Zhu Y, Tao R, Jiang Y, Lu Y, Tong J. Two-thumb-encircling hands technique is more advisable than 2-finger technique when lone rescuer performs cardiopulmonary resuscitation on infant manikin. *Am J Emerg Med*. 2015;33:531–534. doi: 10.1016/j.ajem.2015.01.025
318. Jo CH, Cho GC, Lee CH. Two-thumb encircling technique over the head of patients in the setting of lone rescuer infant CPR occurred during ambulance transfer: a crossover simulation study. *Pediatr Emerg Care*. 2017;33:462–466. doi: 10.1097/pec.0000000000000833
319. Jo CH, Jung HS, Cho GC, Oh YJ. Over-the-head two-thumb encircling technique as an alternative to the two-finger technique in the in-hospital infant cardiac arrest setting: a randomised crossover simulation study. *Emerg Med J*. 2015;32:703–707. doi: 10.1136/emermed-2014-203873
320. Jung WJ, Hwang SO, Kim HI, Cha YS, Kim OH, Kim H, Lee KH, Cha KC. "Knocking-fingers" chest compression technique in infant cardiac arrest: single-rescuer manikin study. *Eur J Emerg Med*. 2019;26:261–265. doi: 10.1097/mej.0000000000000539
321. Ladny JR, Smereka J, Rodríguez-Núñez A, Leung S, Ruetzler K, Szarpak L. Is there any alternative to standard chest compression techniques in infants? A randomized manikin trial of the new "2-thumb-fist" option. *Medicine (Baltimore)*. 2018;97:e9386. doi: 10.1097/md.0000000000009386
322. Lee SU, Kim DK, Chang I, Jung JY, Paek SH, Park JW, Lee JH, Kwak YH. Two-thumb encircling technique with a novel compression assist device provides safe and effective chest compressions in infants. *Pediatr Emerg Care*. 2020;36:e700–e703. doi: 10.1097/pec.0000000000001738
323. Lee SY, Hong JY, Oh JH, Son SH. The superiority of the two-thumb over the two-finger technique for single-rescuer infant cardiopulmonary resuscitation. *Eur J Emerg Med*. 2018;25:372–376. doi: 10.1097/mej.0000000000000461
324. Paek SH, Kim DK, Lee JH, Kwak YH. Comparison of standard and alternative methods for chest compressions in a single rescuer infant CPR: a prospective simulation study. *PLoS One*. 2019;14:e0226632. doi: 10.1371/journal.pone.0226632
325. Pellegrino JL, Bogumil D, Epstein JL, Burke RV. Two-thumb-encircling advantageous for lay responder infant CPR: a randomised manikin study. *Arch Dis Child*. 2019;104:530–534. doi: 10.1136/archdischild-2018-314893
326. Reynolds C, Cox J, Livingstone V, Dempsey EM. Rescuer exertion and fatigue using two-thumb vs. two-finger method during simulated neonatal cardiopulmonary resuscitation. *Front Pediatr*. 2020;8:133. doi: 10.3389/fped.2020.00133
327. Rodriguez-Ruiz E, Martínez-Puga A, Carballo-Fazanes A, Abelairas-Gómez C, Rodríguez-Nuñez A. Two new chest compression methods might challenge the standard in a simulated infant model. *Eur J Pediatr*. 2019;178:1529–1535. doi: 10.1007/s00431-019-03452-2
328. Saini SS, Gupta N, Kumar P, Bhalla AK, Kaur H. A comparison of two-fingers technique and two-thumbs encircling hands technique of chest compression in neonates. *J Perinatol*. 2012;32:690–694. doi: 10.1038/jp.2011.167
329. Smereka J, Bielski K, Ladny JR, Ruetzler K, Szarpak L. Evaluation of a newly developed infant chest compression technique: a randomized crossover manikin trial. *Medicine (Baltim)*. 2017;96:e5915. doi: 10.1097/md.0000000000005915
330. Smereka J, Kasiński M, Smereka A, Ładny JR, Szarpak L. The quality of a newly developed infant chest compression method applied by paramedics: a randomised crossover manikin trial. *Kardiol Pol*. 2017;75:589–595. doi: 10.5603/KP.a2017.0015
331. Smereka J, Szarpak L, Ladny JR, Rodriguez-Nunez A, Ruetzler K. A novel method of newborn chest compression: a randomized crossover simulation study. *Front Pediatr*. 2018;6:159. doi: 10.3389/fped.2018.00159
332. Smereka J, Szarpak L, Rodríguez-Núñez A, Ladny JR, Leung S, Ruetzler K. A randomized comparison of three chest compression techniques and associated hemodynamic effect during infant CPR: a randomized manikin study. *Am J Emerg Med*. 2017;35:1420–1425. doi: 10.1016/j.ajem.2017.04.024
333. Smereka J, Szarpak L, Smereka A, Leung S, Ruetzler K. Evaluation of new two-thumb chest compression technique for infant CPR performed by novice physicians: a randomized, crossover, manikin trial. *Am J Emerg Med*. 2017;35:604–609. doi: 10.1016/j.ajem.2016.12.045
334. Udassi S, Udassi JP, Lamb MA, Theriaque DW, Shuster JJ, Zaritsky AL, Haque IU. Two-thumb technique is superior to two-finger technique during lone rescuer infant manikin CPR. *Resuscitation*. 2010;81:712–717. doi: 10.1016/j.resuscitation.2009.12.029
335. Whitelaw CC, Slywka B, Goldsmith LJ. Comparison of a two-finger versus two-thumb method for chest compressions by healthcare providers in an infant mechanical model. *Resuscitation*. 2000;43:213–216. doi: 10.1016/s0300-9572(99)00145-8
336. Yang D, Kim KH, Oh JH, Son S, Cho J, Seo KM. Development and evaluation of a new chest compression technique for cardiopulmonary resuscitation in infants. *Pediatr Cardiol*. 2019;40:1217–1223. doi: 10.1007/s00246-019-02135-x
337. Na JU, Choi PC, Lee HJ, Shin DH, Han SK, Cho JH. A vertical two-thumb technique is superior to the two-thumb encircling technique for infant cardiopulmonary resuscitation. *Acta Paediatr*. 2015;104:e70–e75. doi: 10.1111/apa.12857
338. Kim YS, Oh JH, Kim CW, Kim SE, Lee DH, Hong JY. Which fingers should we perform two-finger chest compression technique with when performing cardiopulmonary resuscitation on an infant in cardiac arrest? *J Korean Med Sci*. 2016;31:997–1002. doi: 10.3346/jkms.2016.31.6.997
339. Park JW, Jung JY, Kim J, Kwak YH, Kim DK, Lee JC, Ham EM, Hwang S, Kwon H. A novel infant chest compression assist device using a palm rather than fingers: a randomized crossover trial. *Prehosp Emerg Care*. 2019;23:74–82. doi: 10.1080/10903127.2018.1471559
340. Martin PS, Kemp AM, Theobald PS, Maguire SA, Jones MD. Do chest compressions during simulated infant CPR comply with international recommendations? *Arch Dis Child*. 2013;98:576–581. doi: 10.1136/archdischild-2012-302583
341. Ramachandran S, Bruckner M, Wyckoff MH, Smölzer GM; International Liaison Committee on Resuscitation Neonatal Life Support Task Force. Compression ventilation ratio for neonatal CPR: NLS 5504 TF ScR. Accessed February 17, 2023. https://costr.ilcor.org/document/compression-ventilation-ratio-for-neonatal-cpr-nls-5504-tf-scr
342. Aggelina A, Pantazopoulos I, Giokas G, Chalkias A, Mavrovounis G, Papalois A, Douvanas A, Xanthos T, Iacovidou N. Continuous chest compressions with asynchronous ventilation improve survival in a neonatal swine model of asphyxial cardiac arrest. *Am J Emerg Med*. 2021;48:60–66. doi: 10.1016/j.ajem.2021.04.009
343. Boldingh AM, Jensen TH, Bjørbekk AT, Solevåg AL, Nakstad B. Rescuers' physical fatigue with different chest compression to ventilation methods during simulated infant cardiopulmonary resuscitation. *J Matern Fetal Neonatal Med*. 2016;29:3202–3207. doi: 10.3109/14767058.2015.1119115
344. Boldingh AM, Solevåg AL, Aasen E, Nakstad B. Resuscitators who compared four simulated infant cardiopulmonary resuscitation methods favoured the three-to-one compression-to-ventilation ratio. *Acta Paediatr*. 2016;105:910–916. doi: 10.1111/apa.13339
345. Dellimore KH, Scheffer C, Smith J, Van Den Heever DJ, Lloyd DL. Evaluating the influence of ventilation and ventilation-compression synchronization on chest compression force and depth during simulated neonatal

resuscitation. *J Matern Fetal Neonatal Med*. 2017;30:1255–1260. doi: 10.1080/14767058.2016.1210595
346. Hemway RJ, Christman C, Perlman J. The 3:1 is superior to a 15:2 ratio in a newborn manikin model in terms of quality of chest compressions and number of ventilations. *Arch Dis Child Fetal Neonatal Ed*. 2013;98:F42–F45. doi: 10.1136/archdischild-2011-301334
347. Li ES, Cheung PY, O'Reilly M, Aziz K, Schmölzer GM. Rescuer fatigue during simulated neonatal cardiopulmonary resuscitation. *J Perinatol*. 2015;35:142–145. doi: 10.1038/jp.2014.165
348. Li ES, Görens I, Cheung PY, Lee TF, Lu M, O'Reilly M, Schmölzer GM. Chest compressions during sustained inflations improve recovery when compared to a 3:1 compression:ventilation ratio during cardiopulmonary resuscitation in a neonatal porcine model of asphyxia. *Neonatology*. 2017;112:337–346. doi: 10.1159/000477998
349. Mendler MR, Maurer M, Hassan MA, Huang L, Waitz M, Mayer B, Hummler HD. Different techniques of respiratory support do not significantly affect gas exchange during cardiopulmonary resuscitation in a newborn piglet model. *Neonatology*. 2015;108:73–80. doi: 10.1159/000381416
350. Mendler MR, Weber C, Hassan MA, Huang L, Waitz M, Mayer B, Hummler HD. Effect of different respiratory modes on return of spontaneous circulation in a newborn piglet model of hypoxic cardiac arrest. *Neonatology*. 2016;109:22–30. doi: 10.1159/000439020
351. Mustofa J, Cheung PY, Patel S, Lee TF, Lu M, Pasquin MP, O'Reilly M, Schmölzer GM. Effects of different durations of sustained inflation during cardiopulmonary resuscitation on return of spontaneous circulation and hemodynamic recovery in severely asphyxiated piglets. *Resuscitation*. 2018;129:82–89. doi: 10.1016/j.resuscitation.2018.06.013
352. Pasquin MP, Cheung PY, Patel S, Lu M, Lee TF, Wagner M, O'Reilly M, Schmölzer GM. Comparison of different compression to ventilation ratios (2: 1, 3: 1, and 4: 1) during cardiopulmonary resuscitation in a porcine model of neonatal asphyxia. *Neonatology*. 2018;114:37–45. doi: 10.1159/000487988
353. Patel S, Cheung PY, Lee TF, Pasquin MP, Lu M, O'Reilly M, Schmölzer GM. Asynchronous ventilation at 120 compared with 90 or 100 compressions per minute improves haemodynamic recovery in asphyxiated newborn piglets. *Arch Dis Child Fetal Neonatal Ed*. 2020;105:357–363. doi: 10.1136/archdischild-2018-316610
354. Schmölzer GM, O'Reilly MO, Fray C, van Os S, Cheung PY. Chest compression during sustained inflation versus 3:1 chest compression:ventilation ratio during neonatal cardiopulmonary resuscitation: a randomised feasibility trial. *Arch Dis Child Fetal Neonatal Ed*. 2018;103:F455–F460. doi: 10.1136/archdischild-2017-313037
355. Schmölzer GM, O'Reilly M, Labossiere J, Lee TF, Cowan S, Nicoll J, Bigam DL, Cheung PY. 3:1 Compression to ventilation ratio versus continuous chest compression with asynchronous ventilation in a porcine model of neonatal resuscitation. *Resuscitation*. 2014;85:270–275. doi: 10.1016/j.resuscitation.2013.10.011
356. Schmölzer GM, O'Reilly M, Labossiere J, Lee TF, Cowan S, Qin S, Bigam DL, Cheung PY. Cardiopulmonary resuscitation with chest compressions during sustained inflations: a new technique of neonatal resuscitation that improves recovery and survival in a neonatal porcine model. *Circulation*. 2013;128:2495–2503. doi: 10.1161/circulationaha.113.002289
357. Solevåg AL, Dannevig I, Wyckoff M, Saugstad OD, Nakstad B. Return of spontaneous circulation with a compression:ventilation ratio of 15:2 versus 3:1 in newborn pigs with cardiac arrest due to asphyxia. *Arch Dis Child Fetal Neonatal Ed*. 2011;96:F417–F421. doi: 10.1136/adc.2010.200386
358. Solevåg AL, Madland JM, Gjærum E, Nakstad B. Minute ventilation at different compression to ventilation ratios, different ventilation rates, and continuous chest compressions with asynchronous ventilation in a newborn manikin. *Scand J Trauma Resusc Emerg Med*. 2012;20:73. doi: 10.1186/1757-7241-20-73
359. Srikantan SK, Berg RA, Cox T, Tice L, Nadkarni VM. Effect of one-rescuer compression/ventilation ratios on cardiopulmonary resuscitation in infant, pediatric, and adult manikins. *Pediatr Crit Care Med*. 2005;6:293–297. doi: 10.1097/01.Pcc.0000161621.74554.15
360. Vali P, Chandrasekharan P, Rawat M, Gugino S, Koenigsknecht C, Helman J, Mathew B, Berkelhamer S, Nair J, Lakshminrusimha S. Continuous chest compressions during sustained inflations in a perinatal asphyxial cardiac arrest lamb model. *Pediatr Crit Care Med*. 2017;18:e370–e377. doi: 10.1097/pcc.0000000000001248
361. Vali P, Lesneski A, Hardie M, Alhassen Z, Chen P, Joudi H, Sankaran D, Lakshminrusimha S. Continuous chest compressions with asynchronous ventilations increase carotid blood flow in the perinatal asphyxiated lamb model. *Pediatr Res*. 2021;90:752–758. doi: 10.1038/s41390-020-01306-4
362. Ramachandran S, Bruckner M, Wyckoff MH, Smölzer GM; International Liaison Committee on Resuscitation Neonatal Life Support Task Force. Use of feedback CPR devices for neonatal cardiac arrest: NLS 5505 TF ScR. Accessed February 17, 2023. https://costr.ilcor.org/document/use-of-feedback-cpr-devices-for-neonatal-cardiac-arrest-nls-5505-tf-scr
363. Andriessen P, Oetomo SB, Chen W, Feijs LM. Efficacy of feed forward and feedback signaling for inflations and chest compression pressure during cardiopulmonary resuscitation in a newborn mannequin. *J Clin Med Res*. 2012;4:274–278. doi: 10.4021/jocmr865w
364. Austin AL, Spalding CN, Landa KN, Myer BR, Cure D, Smith JE, Platt G, King HC. A randomized control trial of cardiopulmonary feedback devices and their impact on infant chest compression quality: a simulation study. *Pediatr Emerg Care*. 2020;36:e79–e84. doi: 10.1097/pec.0000000000001312
365. Dold SK, Schmölzer GM, Kelm M, Davis PG, Schmalisch G, Roehr CC. Training neonatal cardiopulmonary resuscitation: can it be improved by playing a musical prompt? A pilot study. *Am J Perinatol*. 2014;31:245–248. doi: 10.1055/s-0033-1345261
366. Fuerch JH, Yamada NK, Coelho PR, Lee HC, Halamek LP. Impact of a novel decision support tool on adherence to Neonatal Resuscitation Program algorithm. *Resuscitation*. 2015;88:52–56. doi: 10.1016/j.resuscitation.2014.12.016
367. Jeon SA, Chang H, Yoon SY, Hwang N, Kim K, Yoon H, Hwang SY, Shin TG, Cha WC, Kim T. Effectiveness of smartwatch guidance for high-quality infant cardiopulmonary resuscitation: a simulation study. *Medicina (Kaunas)*. 2021;57:193. doi: 10.3390/medicina57030193
368. Kandasamy J, Theobald PS, Maconochie IK, Jones MD. Can real-time feedback improve the simulated infant cardiopulmonary resuscitation performance of basic life support and lay rescuers? *Arch Dis Child*. 2019;104:793–801. doi: 10.1136/archdischild-2018-316576
369. Kim CW, Oh JH. Effect of metronome guidance on infant cardiopulmonary resuscitation. *Eur J Pediatr*. 2019;178:795–801. doi: 10.1007/s00431-019-03357-0
370. Martin P, Theobald P, Kemp A, Maguire S, Maconochie I, Jones M. Real-time feedback can improve infant manikin cardiopulmonary resuscitation by up to 79%: a randomised controlled trial. *Resuscitation*. 2013;84:1125–1130. doi: 10.1016/j.resuscitation.2013.03.029
371. Roehr CC, Schmölzer GM, Thio M, Dawson JA, Dold SK, Schmalisch G, Davis PG. How ABBA may help improve neonatal resuscitation training: auditory prompts to enable coordination of manual inflations and chest compressions. *J Paediatr Child Health*. 2014;50:444–448. doi: 10.1111/jpc.12507
372. Solevåg AL, Cheung PY, Li E, Aziz K, O'Reilly M, Fu B, Zheng B, Schmölzer G. Quantifying force application to a newborn manikin during simulated cardiopulmonary resuscitation. *J Matern Fetal Neonatal Med*. 2016;29:1770–1772. doi: 10.3109/14767058.2015.1061498
373. Solevag AL, Cheung PY, Li E, Xue SZ, O'Reilly M, Fu B, Zheng B, Schmolzer G. Chest compression quality in a newborn manikin: a randomized crossover trial (August 2016). *IEEE J Transl Eng Health Med*. 2018;6:1900405. doi: 10.1109/jtehm.2018.2863359
374. Chalak LF, Barber CA, Hynan L, Garcia D, Christie L, Wyckoff MH. End-tidal CO_2 detection of an audible heart rate during neonatal cardiopulmonary resuscitation after asystole in asphyxiated piglets. *Pediatr Res*. 2011;69:401–405. doi: 10.1203/PDR.0b013e3182125f7f
375. Chandrasekharan P, Vali P, Rawat M, Mathew B, Gugino SF, Koenigsknecht C, Helman J, Nair J, Berkelhamer S, Lakshminrusimha S. Continuous capnography monitoring during resuscitation in a transitional large mammalian model of asphyxial cardiac arrest. *Pediatr Res*. 2017;81:898–904. doi: 10.1038/pr.2017.26
376. Hamrick JL, Hamrick JT, Lee JK, Lee BH, Koehler RC, Shaffner DH. Efficacy of chest compressions directed by end-tidal CO_2 feedback in a pediatric resuscitation model of basic life support. *J Am Heart Assoc*. 2014;3:e000450. doi: 10.1161/jaha.113.000450
377. Hamrick JT, Hamrick JL, Bhalala U, Armstrong JS, Lee JH, Kulikowicz E, Lee JK, Kudchadkar SR, Koehler RC, Hunt EA, et al. End-tidal CO_2-guided chest compression delivery improves survival in a neonatal asphyxial cardiac arrest model. *Pediatr Crit Care Med*. 2017;18:e575–e584. doi: 10.1097/pcc.0000000000001299
378. Maher KO, Berg RA, Lindsey CW, Simsic J, Mahle WT. Depth of sternal compression and intra-arterial blood pressure during CPR in infants following cardiac surgery. *Resuscitation*. 2009;80:662–664. doi: 10.1016/j.resuscitation.2009.03.016
379. Stine CN, Koch J, Brown LS, Chalak L, Kapadia V, Wyckoff MH. Quantitative end-tidal CO(2) can predict increase in heart rate during infant cardiopulmonary resuscitation. *Heliyon*. 2019;5:e01871. doi: 10.1016/j.heliyon.2019.e01871

380. Oczkowski SJ, Mazzetti I, Cupido C, Fox-Robichaud AE. The offering of family presence during resuscitation: a systematic review and meta-analysis. *J Intensive Care*. 2015;3:41. doi: 10.1186/s40560-015-0107-2
381. Porter J, Cooper SJ, Sellick K. Attitudes, implementation and practice of family presence during resuscitation (FPDR): a quantitative literature review. *Int Emerg Nurs*. 2013;21:26–34. doi: 10.1016/j.ienj.2012.04.002
382. Deacon A, O'Neill TA, Gilfoyle E. A scoping review of the impact of family presence on pediatric resuscitation team members. *Pediatr Crit Care Med*. 2020;21:e1140–e1147. doi: 10.1097/pcc.0000000000002471
383. De Robertis E, Romano GM, Hinkelbein J, Piazza O, Sorriento G. Family presence during resuscitation: a concise narrative review. *Trends Anaesth Crit Care*. 2017;15:12–16. doi: https://doi.org/10.1016/j.tacc.2017.06.001
384. Dainty KN, Atkins DL, Breckwoldt J, Maconochie I, Schexnayder SM, Skrifvars MB, Tijssen J, Wyllie J, Furuta M, Aickin R, et al; International Liaison Committee on Resuscitation's (ILCOR) Pediatric, Neonatal Life Support Task Force, Education, Implementation, and Teams Task Force. Family presence during resuscitation in paediatric and neonatal cardiac arrest: a systematic review. *Resuscitation*. 2021;162:20. doi: 10.1016/j.resuscitation.2021.01.017
385. Considine J, Eastwood K, Webster H, Smyth M, Nation K, Greif R, Dainty K, Finn J, Bray J; International Liaison Committee on Resuscitation (ILCOR) Education, Implementation, and Teams; Basic Life Support; Advanced Life Support Task Forces. Family presence during adult resuscitation from cardiac arrest: a systematic review. *Resuscitation*. 2022;180:11–23. doi: 10.1016/j.resuscitation.2022.08.021
386. Considine J, Eastwood KJ, Webster H, Smyth M, Nation K, Greif R, Dainty KN, Finn J, Bray J, International Committee on Resuscitation's (ILCOR) Education, Implementation and Teams, Basic Life Support, and Advances Life Support Task Forces. Effect of family presence during resuscitation in adult cardiac arrest on patient, family, and health care provider outcomes; EIT TFSR. Updated December 5, 2022. Accessed February 14, 2023. https://costr.ilcor.org/document/effect-of-family-presence-during-resuscitation-in-adult-cardiac-arrest-on-patient-family-and-health-care-provider-outcomes-eit-tfsr
387. Celik C, Celik GS, Buyukcam F. The witness of the patient's relatives increases the anxiety of the physician, but decreases the anxiety of the relatives of the patient. *Hong Kong J Emerg Med*. 2021;28:338. doi: 10.1177/1024907919860632
388. Jabre P, Belpomme V, Azoulay E, Jacob L, Bertrand L, Lapostolle F, Tazarourte K, Bouillet G, Pinaud V, Broche C, et al. Family presence during cardiopulmonary resuscitation. *N Engl J Med*. 2013;368:1008–1018. doi: 10.1056/NEJMoa1203366
389. Krochmal RL, Blenko JW, Afshar M, Netzer G, Roy SC, Wiegand DL, Shanholtz CB. Family presence at first cardiopulmonary resuscitation and subsequent limitations on care in the medical intensive care unit. *Am J Crit Care*. 2017;26:221–228. doi: 10.4037/ajcc2017510
390. Wang CH, Chang WT, Huang CH, Tsai MS, Yu PH, Wu YW, Chen WJ. Factors associated with the decision to terminate resuscitation early for adult in-hospital cardiac arrest: influence of family in an East Asian society. *PLoS One*. 2019;14:e0213168. doi: 10.1371/journal.pone.0213168
391. Metzger K, Gamp M, Tondorf T, Hochstrasser S, Becker C, Luescher T, Rasiah R, Boerlin A, Tisljar K, Emsden C, et al. Depression and anxiety in relatives of out-of-hospital cardiac arrest patients: results of a prospective observational study. *J Crit Care*. 2019;51:57–63. doi: 10.1016/j.jcrc.2019.01.026
392. Soleimanpour H, Tabrizi JS, Rouhi AJ, Golzari SEJ, Mahmoodpoor A, Esfanjani RM, Soleimanpour M. Psychological effects on patient's relatives regarding their presence during resuscitation. *J Cardiovasc Thorac Res*. 2017;9:113–117. doi: 10.15171/jcvtr.2017.19
393. Compton S, Levy P, Griffin M, Waselewsky D, Mango L, Zalenski R. Family-witnessed resuscitation: bereavement outcomes in an urban environment. *J Palliat Med*. 2011;14:715–721. doi: 10.1089/jpm.2010.0463
394. Belanger MA, Reed S. A rural community hospital's experience with family-witnessed resuscitation. *J Emerg Nurs*. 1997;23:238–239. doi: 10.1016/s0099-1767(97)90015-5
395. Post H. Sudden death in the emergency department: survivors speak of their presence during resuscitation. *Care Giver*. 1986;3:152–156. doi: 10.1080/10778586.1986.10767528
396. Magowan E, Melby V. A survey of emergency department staff's opinions and experiences of family presence during invasive procedures and resuscitation. *Emerg Nurse*. 2019;27:13–19. doi: 10.7748/en.2019.e1908
397. Sak-Dankosky N, Andruszkiewicz P, Sherwood PR, Kvist T. Factors associated with experiences and attitudes of healthcare professionals towards family-witnessed resuscitation: a cross-sectional study. *J Adv Nurs*. 2015;71:2595–2608. doi: 10.1111/jan.12736
398. Ganz FD, Yoffe F. Intensive care nurses' perspectives of family-centered care and their attitudes toward family presence during resuscitation. *J Cardiovasc Nurs*. 2012;27:220–227. doi: 10.1097/JCN.0b013e31821888b4
399. Oman KS, Duran CR. Health care providers' evaluations of family presence during resuscitation. *J Emerg Nurs*. 2010;36:524–533. doi: 10.1016/j.jen.2010.06.014
400. Axelsson AB, Fridlund B, Moons P, Mårtensson J, op Reimer WS, Smith K, Strömberg A, Thompson DR, Norekvål TM. European cardiovascular nurses' experiences of and attitudes towards having family members present in the resuscitation room. *Eur J Cardiovasc Nurs*. 2010;9:15–23. doi: 10.1016/j.ejcnurse.2009.10.001
401. Badir A, Sepit D. Family presence during CPR: a study of the experiences and opinions of Turkish critical care nurses. *Int J Nurs Stud*. 2007;44:83–92. doi: 10.1016/j.ijnurstu.2005.11.023
402. Boyd R, White S. Does witnessed cardiopulmonary resuscitation alter perceived stress in accident and emergency staff? *Eur J Emerg Med*. 2000;7:51–53. doi: 10.1097/00063110-200003000-00010
403. Compton S, Grace H, Madgy A, Swor RA. Post-traumatic stress disorder symptomology associated with witnessing unsuccessful out-of-hospital cardiopulmonary resuscitation. *Acad Emerg Med*. 2009;16:226–229. doi: 10.1111/j.1553-2712.2008.00336.x
404. Waldemar A, Bremer A, Holm A, Strömberg A, Thylén I. In-hospital family-witnessed resuscitation with a focus on the prevalence, processes, and outcomes of resuscitation: a retrospective observational cohort study. *Resuscitation*. 2021;165:23–30. doi: 10.1016/j.resuscitation.2021.05.031
405. De Stefano C, Normand D, Jabre P, Azoulay E, Kentish-Barnes N, Lapostolle F, Baubet T, Reuter P-G, Javaud N, Borron SW. Family presence during resuscitation: a qualitative analysis from a national multicenter randomized clinical trial. *PLoS One*. 2016;11:e0156100. doi: 10.1371/journal.pone.0156100. eCollection 2016
406. Masa'Deh R, Saifan A, Timmons S, Nairn S. Families' stressors and needs at time of cardio-pulmonary resuscitation: a Jordanian perspective. *Glob Gournal Health Sci*. 2014;6:72–85. doi: 10.5539/gjhs.v6n2p72
407. Weslien M, Nilstun T, Lundqvist A, Fridlund B. Narratives about resuscitation: family members differ about presence. *Eur J Cardiovasc Nurs*. 2006;5:68–74. doi: 10.1016/j.ejcnurse.2005.08.002
408. van der Woning M. Relatives in the resuscitation area: a phenomenological study. *Nurs Crit Care*. 1999;4:186.
409. Giles T, de Lacey S, Muir-Cochrane E. How do clinicians practise the principles of beneficence when deciding to allow or deny family presence during resuscitation? *J Clin Nurs*. 2018;27:e1214. doi: 10.1111/jocn.14222
410. Bremer A, Dahlberg K, Sandman L. Balancing between closeness and distance: emergency medical services personnel's experiences of caring for families at out-of-hospital cardiac arrest and sudden death. *Prehosp Disaster Med*. 2012;27:42–52. doi: 10.1017/S1049023X12000167
411. Giles T, de Lacey S, Muir-Cochrane E. Factors influencing decision-making around family presence during resuscitation: a grounded theory study. *J Adv Nurs*. 2016;72:2706–2717. doi: 10.1111/jan.13046
412. Hassankhani H, Zamanzade V, Rahmani A, Haririan H, Porter JE. Family support liaison in the witnessed resuscitation: a phenomenology study. *Int J Nurs Stud*. 2017B;74:95–100. doi: 10.1016/j.ijnurstu.2017.06.005
413. Hassankhani H, Zamanzadeh V, Rahmani A, Haririan H, Porter JE. Family presence during resuscitation: a double-edged sword. *J Nurs Scholarsh*. 2017A;49:127–134. doi: 10.1111/jnu.12273
414. Meyers TA, Eichhorn DJ, Guzzetta CE, Clark AP, Klein JD, Taliaferro E, Calvin A. Family presence during invasive procedures and resuscitation: the experience of family members, nurses, and physicians. *Am J Nurs*. 2000;100:32–42; quiz 43.
415. Monks J, Flynn M. Care, compassion and competence in critical care: a qualitative exploration of nurses' experience of family witnessed resuscitation. *Intensive Crit Care Nurs*. 2014;30:353–359. doi: 10.1016/j.iccn.2014.04.006
416. Wagner JM. Lived experience of critically ill patients' family members during cardiopulmonary resuscitation. *Am J Crit Care*. 2004;13:416–420.
417. Walker WM. Emergency care staff experiences of lay presence during adult cardiopulmonary resuscitation: a phenomenological study. *Emerg Med J*. 2014;31:453–458. doi: 10.1136/emermed-2012-201984
418. Walker M, Peyton JWR. Teaching in the theatre. In: Peyton JWR., ed. *Teaching and Learning in Medical Practice*. Manticore Publishers Europe; 1998:171–180.
419. Bullock I. Skill acquisition in resuscitation. *Resuscitation*. 2000;45:139–143. doi: 10.1016/s0300-9572(00)00171-4
420. Barelli A, Scapigliati A. The four-stage approach to teaching skills: the end of a dogma? *Resuscitation*. 2010;81:1607–1608. doi: 10.1016/j.resuscitation.2010.09.010

421. Gradl-Dietsch G, Hitpaß L, Gueorguiev B, Nebelung S, Schrading S, Knobe M. Undergraduate curricular training in musculoskeletal ultrasound by student teachers: the impact of Peyton's four-step approach. *Z Orthop Unfall*. 2019;157:270–278. doi: 10.1055/a-0715-2435
422. Breckwoldt J, Lockey A, Yeung J, Cheng A, Lauridsen KG, Greif R; International Liaison Committee on Resuscitation Education Implementation and Teams Task Force. Stepwise approach to skills teaching in resuscitation: EIT 6402 TFSR. Updated December 18, 2022. Accessed February 14, 2023. Accessed. https://costr.ilcor.org/document/stepwise-approach-to-skills-teaching-in-resuscitation-eit-6402-tfsr
423. Archer E, van Hoving DJ, de Villiers A. In search of an effective teaching approach for skill acquisition and retention: teaching manual defibrillation to junior medical students. *African J Emerg Med*. 2015;5:54–59. doi: https://doi.org/10.1016/j.afjem.2014.10.009
424. Bjørnshave K, Krogh LQ, Hansen SB, Nebsbjerg MA, Thim T, Løfgren B. Teaching basic life support with an automated external defibrillator using the two-stage or the four-stage teaching technique. *Eur J Emerg Med*. 2018;25:18–24. doi: 10.1097/mej.0000000000000410
425. Bomholt KB, Krogh LQ, Bomholt SR, Nebsbjerg MA, Thim T, Løfgren B. Three-month retention of basic life support with an automated external defibrillator using a two-stage versus four-stage teaching technique. *Biomed Res Int*. 2019;2019:1394972. doi: 10.1155/2019/1394972
426. Frangez M, Jenko M, GradisEk P, Kamenik M. Medical students perform basic life support skills in a simulated scenario better using a 4-stage teaching approach compared to conventional training. *Signa Vitae*. 2017;13:61–64.
427. Greif R, Egger L, Basciani RM, Lockey A, Vogt A. Emergency skill training: a randomized controlled study on the effectiveness of the 4-stage approach compared to traditional clinical teaching. *Resuscitation*. 2010;81:1692–1697. doi: 10.1016/j.resuscitation.2010.09.478
428. Herrmann-Werner A, Nikendei C, Keifenheim K, Bosse HM, Lund F, Wagner R, Celebi N, Zipfel S, Weyrich P. "Best practice" skills lab training vs. a "see one, do one" approach in undergraduate medical education: an RCT on students' long-term ability to perform procedural clinical skills. *PLoS One*. 2013;8:e76354. doi: 10.1371/journal.pone.0076354
429. Jenko M, Frangez M, Manohin A. Four-stage teaching technique and chest compression performance of medical students compared to conventional technique. *Croat Med J*. 2012;53:486–495. doi: 10.3325/cmj.2012.53.486
430. Krautter M, Weyrich P, Schultz JH, Buss SJ, Maatouk I, Jünger J, Nikendei C. Effects of Peyton's four-step approach on objective performance measures in technical skills training: a controlled trial. *Teach Learn Med*. 2011;23:244–250. doi: 10.1080/10401334.2011.586917
431. Lapucci G, Bondi B, Rubbi I, Cremonini V, Moretti E, Di Lorenzo R, Magnani D, Ferri P. A randomized comparison trial of two and four-step approaches to teaching cardio-pulmonary reanimation. *Acta Biomed*. 2018;89:37–44. doi: 10.23750/abm.v89i4-S.7129
432. Münster T, Stosch C, Hindrichs N, Franklin J, Matthes J. Peyton's 4-steps-approach in comparison: medium-term effects on learning external chest compression: a pilot study. *GMS J Med Educ*. 2016;33:Doc60. doi: 10.3205/zma001059
433. Nourkami-Tutdibi N, Hilleke AB, Zemlin M, Wagenpfeil G, Tutdibi E. Novel modified Peyton's approach for knowledge retention on newborn life support training in medical students. *Acta Paediatr*. 2020;109:1570–1579. doi: 10.1111/apa.15198
434. Orde S, Celenza A, Pinder M. A randomised trial comparing a 4-stage to 2-stage teaching technique for laryngeal mask insertion. *Resuscitation*. 2010;81:1687–1691. doi: https://doi.org/10.1016/j.resuscitation.2010.05.026
435. Schwerdtfeger K, Wand S, Schmid O, Roessler M, Quintel M, Leissner KB, Russo SG. A prospective, blinded evaluation of a video-assisted "4-stage approach" during undergraduate student practical skills training. *BMC Med Educ*. 2014;14:104. doi: 10.1186/1472-6920-14-104
436. Schauwinhold MT, Schmidt M, Rudolph JW, Klasen M, Lambert SI, Krusch A, Vogt L, Sopka S. Innovative tele-instruction approach impacts basic life support performance: a non-inferiority trial. *Front Med (Lausanne)*. 2022;9:825823. doi: 10.3389/fmed.2022.825823
437. Sopka S, Biermann H, Rossaint R, Knott S, Skorning M, Brokmann JC, Heussen N, Beckers SK. Evaluation of a newly developed media-supported 4-step approach for basic life support training. *Scand J Trauma Resusc Emerg Med*. 2012;20:37. doi: 10.1186/1757-7241-20-37
438. Zamani M, Nasr-Esfahani M, Forghani M, Sichani MA, Omid A. Endotracheal intubation training to medical practitioners: comparison of the modified 4-step Payton's training method and Halsted's training method in a simulated environment. *J Educ Health Promot*. 2020;9:126. doi: 10.4103/jehp.jehp_705_19
439. Nicholls D, Sweet L, Muller A, Hyett J. Teaching psychomotor skills in the twenty-first century: revisiting and reviewing instructional approaches through the lens of contemporary literature. *Med Teach*. 2016;38:1056–1063. doi: 10.3109/0142159x.2016.1150984
440. Van Hoeyweghen RJ, Bossaert LL, Mullie A, Calle P, Martens P, Buylaert WA, Delooz H. Quality and efficiency of bystander CPR: Belgian Cerebral Resuscitation Study Group. *Resuscitation*. 1993;26:47–52. doi: 10.1016/0300-9572(93)90162-j
441. Birkun A. Disparities in resuscitation education for people with disabilities: a research gap. *Resuscitation*. 2022;175:32–33. doi: 10.1016/j.resuscitation.2022.04.011
442. Ko YC, Hsieh M-J, Schnaubelt S, Matsuyama T, Cheng A, Greif R; International Liaison Committee on Resuscitation Education Implementation and Teams Task Force. Disparity in layperson resuscitation education: a task force scoping review (EIT 6102). Updated December 14, 2022. Accessed February 14, 2023. https://costr.ilcor.org/document/disparity-in-layperson-resuscitation-education-a-task-force-scoping-review-eit-6102
443. Abdulhay NM, Totolos K, McGovern S, Hewitt N, Bhardwaj A, Buckler DG, Leary M, Abella BS. Socioeconomic disparities in layperson CPR training within a large U.S. city. *Resuscitation*. 2019;141:13–18. doi: 10.1016/j.resuscitation.2019.05.038
444. Alexander TD, McGovern SK, Leary M, Abella BS, Blewer AL. Association of state-level CPR training initiatives with layperson CPR knowledge in the United States. *Resuscitation*. 2019;140:9–15. doi: 10.1016/j.resuscitation.2019.04.037
445. Anderson ML, Cox M, Al-Khatib SM, Nichol G, Thomas KL, Chan PS, Saha-Chaudhuri P, Fosbol EL, Eigel B, Clendenen B, et al. Rates of cardiopulmonary resuscitation training in the United States. *JAMA Intern Med*. 2014;174:194–201. doi: 10.1001/jamainternmed.2013.11320
446. Andrél C, Christensson C, Rehn L, Friberg H, Dankiewicz J. Knowledge and attitudes to cardiopulmonary resuscitation (CPR): a cross-sectional population survey in Sweden. *Resusc Plus*. 2021;5:100071. doi: https://doi.org/10.1016/j.resplu.2020.100071
447. Axelsson AB, Herlitz J, Holmberg S, Thorén AB. A nationwide survey of CPR training in Sweden: foreign born and unemployed are not reached by training programmes. *Resuscitation*. 2006;70:90–97. doi: 10.1016/j.resuscitation.2005.11.009
448. Bakke HK, Steinvik T, Angell J, Wisborg T. A nationwide survey of first aid training and encounters in Norway. *BMC Emerg Med*. 2017;17:6. doi: 10.1186/s12873-017-0116-7
449. Birkun A, Kosova Y. Social attitude and willingness to attend cardiopulmonary resuscitation training and perform resuscitation in the Crimea. *World J Emerg Med*. 2018;9:237–248. doi: 10.5847/wjem.j.1920-8642.2018.04.001
450. Blewer AL, Ibrahim SA, Leary M, Dutwin D, McNally B, Anderson ML, Morrison LJ, Aufderheide TP, Daya M, Idris AH, et al. Cardiopulmonary resuscitation training disparities in the United States. *J Am Heart Assoc*. 2017;6 e006124. doi: 10.1161/jaha.117.006124
451. Cartledge S, Saxton D, Finn J, Bray JE. Australia's awareness of cardiac arrest and rates of CPR training: results from the Heart Foundation's HeartWatch survey. *BMJ Open*. 2020;10:e033722. doi: 10.1136/bmjopen-2019-033722
452. Chair SY, Hung MSY, Lui JCZ, Lee DTF, Shiu IYC, Choi KC. Public knowledge and attitudes towards cardiopulmonary resuscitation in Hong Kong: telephone survey. *Hong Kong Med J*. 2014;20:126–133. doi: 10.12809/hkmj134076
453. Dobbie F, MacKintosh AM, Clegg G, Stirzaker R, Bauld L. Attitudes towards bystander cardiopulmonary resuscitation: results from a cross-sectional general population survey. *PLoS One*. 2018;13:e0193391. doi: 10.1371/journal.pone.0193391
454. Flabouris A. Ethnicity and proficiency in English as factors affecting community cardiopulmonary resuscitation (CPR) class attendance. *Resuscitation*. 1996;32:95–103. doi: 10.1016/0300-9572(96)00942-2
455. Hatzakis KD, Kritsotakis EI, Karadimitri S, Sikioti T, Androulaki ZD. Community cardiopulmonary resuscitation training in Greece. *Res Nurs Health*. 2008;31:165–171. doi: 10.1002/nur.20244
456. Hawkes CA, Brown TP, Booth S, Fothergill RT, Siriwardena N, Zakaria S, Askew S, Williams J, Rees N, Ji C, et al. Attitudes to cardiopulmonary resuscitation and defibrillator use: a survey of UK adults in 2017. *J Am Heart Assoc*. 2019;8:e008267. doi: 10.1161/jaha.117.008267
457. Jennings S, Hara TO, Cavanagh B, Bennett K. A national survey of prevalence of cardiopulmonary resuscitation training and knowledge of the emergency number in Ireland. *Resuscitation*. 2009;80:1039–1042. doi: 10.1016/j.resuscitation.2009.05.023

458. Jensen TW, Folke F, Andersen MP, Blomberg SN, Jørgensen AJ, Holgersen MG, Ersbøll AK, Hendriksen OM, Lippert F, Torp-Pedersen C, et al. Socio-demographic characteristics of basic life support course participants in Denmark. *Resuscitation*. 2022;170:167–177. doi: https://doi.org/10.1016/j.resuscitation.2021.11.006
459. Kuramoto N, Morimoto T, Kubota Y, Maeda Y, Seki S, Takada K, Hiraide A. Public perception of and willingness to perform bystander CPR in Japan. *Resuscitation*. 2008;79:475–481. doi: 10.1016/j.resuscitation.2008.07.005
460. Lejeune PO, Delooz HH. Why did persons invited to train in cardiopulmonary resuscitation not do so? *Eur Heart J*. 1987;8:224–228.
461. Meischke H, Taylor V, Calhoun R, Liu Q, Sos C, Tu SP, Yip MP, Eisenberg D. Preparedness for cardiac emergencies among Cambodians with limited English proficiency. *J Community Health*. 2012;37:176–180. doi: 10.1007/s10900-011-9433-z
462. Owen DD, McGovern SK, Murray A, Leary M, del Rios M, Merchant RM, Abella BS, Dutwin D, Blewer AL. Association of race and socioeconomic status with automatic external defibrillator training prevalence in the United States. *Resuscitation*. 2018;127:100–104. doi: https://doi.org/10.1016/j.resuscitation.2018.03.037
463. Sipsma K, Stubbs BA, Plorde M. Training rates and willingness to perform CPR in King County, Washington: a community survey. *Resuscitation*. 2011;82:564–567. doi: https://doi.org/10.1016/j.resuscitation.2010.12.007
464. Teng Y, Li Y, Xu L, Chen F, Chen H, Jin L, Chen J, Huang J, Xu G. Awareness, knowledge and attitudes towards cardiopulmonary resuscitation among people with and without heart disease relatives in South China: a cross-sectional survey. *BMJ Open*. 2020;10:e041245. doi: 10.1136/bmjopen-2020-041245
465. Vaillancourt C, Charette M, Kasaboski A, Brehaut JC, Osmond M, Wells GA, Stiell IG, Grimshaw J. Barriers and facilitators to CPR knowledge transfer in an older population most likely to witness cardiac arrest: a theory-informed interview approach. *Emerg Med J*. 2014;31:700–705. doi: 10.1136/emermed-2012-202192
466. Böttiger BW, Semeraro F, Wingen S. "Kids Save Lives": educating schoolchildren in cardiopulmonary resuscitation is a civic duty that needs support for implementation. *J Am Heart Association*. 2017;6:e005738. doi: 10.1161/JAHA.117.005738
467. Lorem T, Palm A, Wik L. Impact of a self-instruction CPR kit on 7th graders' and adults' skills and CPR performance. *Resuscitation*. 2008;79:103–108. doi: 10.1016/j.resuscitation.2008.04.030
468. Lukas RP, Van Aken H, Mölhoff T, Weber T, Rammert M, Wild E, Bohn A. Kids Save Lives: a six-year longitudinal study of schoolchildren learning cardiopulmonary resuscitation: who should do the teaching and will the effects last? *Resuscitation*. 2016;101:35–40. doi: 10.1016/j.resuscitation.2016.01.028
469. Juul Grabmayr A, Andelius L, Bo Christensen N, Folke F, Bundgaard Ringgren K, Torp-Pedersen C, Gislason G, Jensen TW, Rolin Kragh A, Tofte Gregers MC, et al. Contemporary levels of cardiopulmonary resuscitation training in Denmark. *Resusc Plus*. 2022;11:100268. doi: 10.1016/j.resplu.2022.100268
470. Garcia RA, Spertus JA, Girotra S, Nallamothu BK, Kennedy KF, McNally BF, Breathett K, Del Rios M, Sasson C, Chan PS. Racial and ethnic differences in bystander CPR for witnessed cardiac arrest. *N Engl J Med*. 2022;387:1569–1578. doi: 10.1056/NEJMoa2200798
471. Hofacker SA, Dupre ME, Vellano K, McNally B, Starks MA, Wolf M, Svetkey LP, Pun PH. Association between patient race and staff resuscitation efforts after cardiac arrest in outpatient dialysis clinics: a study from the CARES surveillance group. *Resuscitation*. 2020;156:42–50. doi: 10.1016/j.resuscitation.2020.07.036
472. Moon S, Bobrow BJ, Vadeboncoeur TF, Kortuem W, Kisakye M, Sasson C, Stolz U, Spaite DW. Disparities in bystander CPR provision and survival from out-of-hospital cardiac arrest according to neighborhood ethnicity. *Am J Emerg Med*. 2014;32:1041–1045. doi: 10.1016/j.ajem.2014.06.019
473. Vadeboncoeur TF, Richman PB, Darkoh M, Chikani V, Clark L, Bobrow BJ. Bystander cardiopulmonary resuscitation for out-of-hospital cardiac arrest in the Hispanic vs the non-Hispanic populations. *Am J Emerg Med*. 2008;26:655–660. doi: 10.1016/j.ajem.2007.10.002
474. King R, Heisler M, Sayre MR, Colbert SH, Bond-Zielinski C, Rabe M, Eigel B, Sasson C. Identification of factors integral to designing community-based CPR interventions for high-risk neighborhood residents. *Prehosp Emerg Care*. 2015;19:308–312. doi: 10.3109/10903127.2014.964889
475. Liu KY, Haukoos JS, Sasson C. Availability and quality of cardiopulmonary resuscitation information for Spanish-speaking population on the Internet. *Resuscitation*. 2014;85:131–137. doi: 10.1016/j.resuscitation.2013.08.274
476. Sasson C, Haukoos JS, Ben-Youssef L, Ramirez L, Bull S, Eigel B, Magid DJ, Padilla R. Barriers to calling 911 and learning and performing cardiopulmonary resuscitation for residents of primarily Latino, high-risk neighborhoods in Denver, Colorado. *Ann Emerg Med*. 2015;65:545–552.e542. doi: 10.1016/j.annemergmed.2014.10.028
477. Schnaubelt S, Schnaubelt B, Pilz A, Oppenauer J, Yildiz E, Schriefl C, Ettl F, Krammel M, Garg R, Niessner A, et al. BLS courses for refugees are feasible and induce commitment towards lay rescuer resuscitation. *Eur J Clin Invest*. 2022;52:e13644. doi: 10.1111/eci.13644
478. Birkun A, Kosova Y. Limited accessibility of free online resuscitation education for people with disabilities. *Am J Emerg Med*. 2022;56:100–103. doi: https://doi.org/10.1016/j.ajem.2022.03.039
479. Singletary EM, Douma M, Kung J, Myhre C, MacKenzie E; International Liaison Committee on Resuscitation First Aid Task Force. Pulse oximetry use in the first aid setting: FATF scoping review. Accessed February 23, 2023. https://costr.ilcor.org/document/pulse-oximetry-use-in-the-first-aid-setting-fatf-scoping-review
480. Crooks CJ, West J, Morling JR, Simmonds M, Juurlink I, Briggs S, Cruickshank S, Hammond-Pears S, Shaw D, Card TR, et al. Pulse oximeter measurements vary across ethnic groups: an observational study in patients with COVID-19. *Eur Respir J*. 2022;59:2103246. doi: 10.1183/13993003.03246-2021
481. Sjoding MW, Dickson RP, Iwashyna TJ, Gay SE, Valley TS. Racial bias in pulse oximetry measurement. *N Engl J Med*. 2020;383:2477–2478. doi: 10.1056/NEJMc2029240
482. Burnett GW, Stannard B, Wax DB, Lin HM, Pyram-Vincent C, DeMaria S, Levin MA. Self-reported race/ethnicity and intraoperative occult hypoxemia: a retrospective cohort study. *Anesthesiology*. 2022;136:688–696. doi: 10.1097/ALN.0000000000004153
483. Wong AI, Charpignon M, Kim H, Josef C, de Hond AAH, Fojas JJ, Tabaie A, Liu X, Mireles-Cabodevila E, Carvalho L, et al. Analysis of discrepancies between pulse oximetry and arterial oxygen saturation measurements by race and ethnicity and association with organ dysfunction and mortality. *JAMA Netw Open*. 2021;4:e2131674. doi: 10.1001/jamanetworkopen.2021.31674
484. Valbuena VSM, Merchant RM, Hough CL. Racial and ethnic bias in pulse oximetry and clinical outcomes. *JAMA Intern Med*. 2022;182:699–700. doi: 10.1001/jamainternmed.2022.1903
485. Fawzy A, Wu TD, Wang K, Robinson ML, Farha J, Bradke A, Golden SH, Xu Y, Garibaldi BT. Racial and ethnic discrepancy in pulse oximetry and delayed identification of treatment eligibility among patients with COVID-19. *JAMA Intern Med*. 2022;182:730–738. doi: 10.1001/jamainternmed.2022.1906
486. Gottlieb ER, Ziegler J, Morley K, Rush B, Celi LA. Assessment of racial and ethnic differences in oxygen supplementation among patients in the intensive care unit. *JAMA Intern Med*. 2022;182:849–858. doi: 10.1001/jamainternmed.2022.2587
487. Nikolaou NI, Welsford M, Beygui F, Bossaert L, Ghaemmaghami C, Nonogi H, O'Connor RE, Pichel DR, Scott T, Walters DL, et al; Acute Coronary Syndrome Chapter Collaborators. Part 5: Acute coronary syndromes: 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. *Resuscitation*. 2015;95:e121–e146. doi: 10.1016/j.resuscitation.2015.07.043
488. Macneil F, Chang WT, Orkin A, Djärv T, Singletary E, Carlson J; International Liaison Committee on Resuscitation First Aid Task Force. FA 7030 use of supplementary oxygen in first aid: FA ScR. Accessed February 23, 2023. https://costr.ilcor.org/document/fa-7030-use-of-supplementary-oxygen-in-first-aid-fa-scr
489. Austin MA, Wills KE, Blizzard L, Walters EH, Wood-Baker R. Effect of high flow oxygen on mortality in chronic obstructive pulmonary disease patients in prehospital setting: randomised controlled trial. *BMJ*. 2010;341:c5462. doi: 10.1136/bmj.c5462
490. Zideman DA, De Buck ED, Singletary EM, Cassan P, Chalkias AF, Evans TR, Hafner CM, Handley AJ, Meyran D, Schunder-Tatzber S, et al. European Resuscitation Council guidelines for resuscitation 2015 Section 9: first aid. *Resuscitation*. 2015;95:278–287. doi: 10.1016/j.resuscitation.2015.07.031
491. Singletary EM, Zideman DA, Bendall JC, Berry DC, Borra V, Carlson JN, Cassan P, Chang WT, Charlton NP, Djarv T, et al; First Aid Science Collaborators. 2020 International Consensus on First Aid Science With Treatment Recommendations. *Circulation*. 2020;142(suppl 1):S284–S334. doi: 10.1161/CIR.0000000000000897
492. Meyran D, Cassan P, Nemeth M, Singletary EM, Raitt J, Djärv T, Carlson JN; International Liaison Committee on Resuscitation First Aid Task Force. Recognition of anaphylaxis: FA 7110 TFScR. Accessed February 23, 2023. https://costr.ilcor.org/document/recognition-of-anaphylaxis-fa-7110-tfscr
493. Brockow K, Schallmayer S, Beyer K, Biedermann T, Fischer J, Gebert N, Grosber M, Jakob T, Klimek L, Kugler C, et al; Working Group on Anaphylaxis Training and Education (AGATE). Effects of a structured educational

intervention on knowledge and emergency management in patients at risk for anaphylaxis. *Allergy*. 2015;70:227–235. doi: 10.1111/all.12548
494. Canon N, Gharfeh M, Guffey D, Anvari S, Davis CM. Role of food allergy education: measuring teacher knowledge, attitudes, and beliefs. *Allergy Rhinol*. 2019;10:2152656719856324. doi: 10.1177/2152656719856324
495. Dumeier HK, Richter LA, Neininger MP, Prenzel F, Kiess W, Bertsche A, Bertsche T. Knowledge of allergies and performance in epinephrine autoinjector use: a controlled intervention in preschool teachers. *Eur J Pediatr*. 2018;177:575–581. doi: 10.1007/s00431-017-3073-y
496. Ferran LR, Tornero NG, Álvarez NC, Piedra FT. Anaphylaxis at school: are we prepared? Could we improve? *Allergol Immunopathol (Madr)*. 2020;48:384–389. doi: 10.1016/j.aller.2019.10.006
497. Gallagher JL, Rivera RD, Shepard KV, Roushan T, Ahsan G, Ahamed SI, Chiu A, Jurken M, Simpson PM, Nugent M, et al. Life-threatening allergies: using a patient-engaged approach. *Telemed e-Health*. 2019;25:319–325. doi: 10.1089/tmj.2018.0046
498. Gonzalez-Mancebo E, Gandolfo-Cano MM, Trujillo-Trujillo MJ, Mohedano-Vicente E, Calso A, Juarez R, Melendez A, Morales P, Pajuelo F. Analysis of the effectiveness of training school personnel in the management of food allergy and anaphylaxis. *Allergol Immunopathol (Madr)*. 2019;47:60–63. doi: 10.1016/j.aller.2018.05.005
499. Jiang J, Gallagher J, Szkodon J, Syed M, Gobin K, Gupta R, Bilaver L. The development and evaluation of peer food allergy education videos for school- age youth. *Ann Allergy Asthma Immunol*. 2019;123:107–108. doi: 10.1016/j.anai.2019.04.002
500. Litarowsky JA, Murphy SO, Canham DL. Evaluation of an anaphylaxis training program for unlicensed assistive personnel. *J Sch Nurs*. 2004;20:279–284. doi: 10.1177/10598405040200050601
501. Polloni L, Baldi I, Lazzarotto F, Bonaguro R, Toniolo A, Gregori D, Muraro A. Multidisciplinary education improves school personnel's self-efficacy in managing food allergy and anaphylaxis. *Pediatr Allergy Immunol*. 2020;31:380–387. doi: 10.1111/pai.13212
502. Soller L, Teoh T, Baerg I, Wong T, Hildebrand KJ, Cook VE, Biggs CM, Lee N, Yaworski L, Cameron SB, et al. Extended analysis of parent and child confidence in recognizing anaphylaxis and using the epinephrine autoinjector during oral food challenges. *J Allergy Clin Immunol*. 2018;7:693–695. doi: 10.1016/j.jaip.2018.09.025
503. Alqurashi W, Awadia A, Pouliot A, Cloutier M, Hotte S, Segal L, Barrowman N, Irwin D, Vaillancourt R. The Canadian Anaphylaxis Action Plan for Kids: development and validation. *Patient Educ Couns*. 2020;103:227–233. doi: 10.1016/j.pec.2019.07.028
504. Korematsu S, Kaku M, Kitada S, Etoh M, Kai H, Joh M, Nakano K, Nakamura M, Sato K, Wakita Y, et al. Anaphylaxis and onsite treatment in schools, kindergartens, and nurseries. *Pediatr Int*. 2022;64:e14973. doi: 10.1111/ped.14973
505. Efthymiou D, Panayi P, Feketea G, Pitsios C, Muntean IA, Vassilopoulou E. Alliance with the school personnel is crucial for the management of food allergy and anaphylaxis in school children. *Foods*. 2021;10:2083. doi: 10.3390/foods10092083
506. Esenboga S, Kahveci M, Cetinkaya PG, Sahiner UM, Soyer O, Buyuktiryaki B, Sekerel BE. Physicians prescribe adrenaline autoinjectors, do parents use them when needed? *Allergol Immunopathol (Madr)*. 2020;48:3–7. doi: 10.1016/j.aller.2019.07.009
507. Glassberg B, Nowak-Wegrzyn A, Wang J. Factors contributing to underuse of epinephrine autoinjectors in pediatric patients with food allergy. *Ann Allergy Asthma Immunol*. 2021;126:175–179.e3. doi: 10.1016/j.anai.2020.09.012
508. Greiwe JC, Pazheri F, Schroer B. Nannies' knowledge, attitude, and management of food allergies of children: an online survey. *J Allergy Clin Immunol*. 2015;3:63–67. doi: 10.1016/j.jaip.2014.07.017
509. Miles LM, Ratnarajah K, Gabrielli S, Abrams EM, Protudjer JLP, Bégin P, Chan ES, Upton J, Waserman S, Watson W, et al. Community use of epinephrine for the treatment of anaphylaxis: a review and meta-analysis. *J Allergy Clin Immunol*. 2021;9:2321–2333. doi: 10.1016/j.jaip.2021.01.038
510. Pflipsen MC, Vega Colon KM. Anaphylaxis: recognition and management. *Am Fam Physician*. 2020;102:355–362.
511. Prince BT, Mikhail I, Stukus DR. Underuse of epinephrine for the treatment of anaphylaxis: missed opportunities. *J Asthma Allergy*. 2018;11:143–151. doi: 10.2147/jaa.s159400
512. Markenson D, Ferguson JD, Chameides L, Cassan P, Chung KL, Epstein JL, Gonzales L, Hazinski MF, Herrington RA, Pellegrino JL, et al; First Aid Chapter Collaborators. Part 13: first aid: 2010 American Heart Association and American Red Cross International Consensus on First Aid Science With Treatment Recommendations. *Circulation*. 2010;122(suppl 2):S582–S605. doi: 10.1161/CIRCULATIONAHA.110.971168
513. Charlton NP, Berry D, Djärv T, Carlson J; International Liaison Committee on Resuscitation First Aid Task Force. FA 7121 potential harms from bronchodilator administration: FA ScR. Accessed February 23, 2023. https://costr.ilcor.org/document/fa-7121-potential-harms-from-bronchodilator-administration-fa-scr
514. Payares-Salamanca L, Contreras-Arrieta S, Florez-Garcia V, Barrios-Sanjuanelo A, Stand-Nino I, Rodriguez-Martinez CE. Metered-dose inhalers versus nebulization for the delivery of albuterol for acute exacerbations of wheezing or asthma in children: a systematic review with meta-analysis. *Pediatr Pulmonol*. 2020;55:3268–3278. doi: 10.1002/ppul.25077
515. Duarte M, Camargos P. Efficacy and safety of a home-made non-valved spacer for bronchodilator therapy in acute asthma. *Acta Paediatr*. 2002;91:909–913. doi: 10.1080/080352502760272579
516. Newhouse MT, Chapman KR, McCallum AL, Abboud RT, Bowie DM, Hodder RV, Pare PD, Mesic-Fuchs H, Molfino NA. Cardiovascular safety of high doses of inhaled fenoterol and albuterol in acute severe asthma. *Chest*. 1996;110:595–603. doi: 10.1378/chest.110.3.595
517. DaCruz D, Holburn C. Serum potassium responses to nebulized salbutamol administered during an acute asthmatic attack. *Arch Emerg Med*. 1989;6:22–26. doi: 10.1136/emj.6.1.22
518. Kenyon CC, Fieldston ES, Luan X, Keren R, Zorc JJ. Safety and effectiveness of continuous aerosolized albuterol in the non-intensive care setting. *Pediatrics*. 2014;134:e976–e982. doi: 10.1542/peds.2014-0907
519. Muchao FP, Souza JM, Torres HC, De Laibera LB, de Souza AV, Rodrigues JC, Schvartsman C, da Silva Filho LV. Albuterol via metered-dose inhaler in children: lower doses are effective, and higher doses are safe. *Pediatr Pulmonol*. 2016;51:1122–1130. doi: 10.1002/ppul.23469
520. Hung CH, Chu DM, Wang CL, Yang KD. Hypokalemia and salbutamol therapy in asthma. *Pediatr Pulmonol*. 1999;27:27–31. doi: 10.1002/(sici)1099-0496(199901)27:1<27::aid-ppul6>3.0.co;2-p
521. Kokulu K, Oner H, Ozen C, Eroglu SE, Altunok I, Akca HS. Pharmacologic anisocoria due to nebulized ipratropium bromide: a diagnostic challenge. *Am J Emerg Med*. 2019;37:1217 e1213–1217 e1214. doi: 10.1016/j.ajem.2019.03.047
522. Spooner LM, Olin JL. Paradoxical bronchoconstriction with albuterol administered by metered-dose inhaler and nebulizer solution. *Ann Pharmacother*. 2005;39:1924–1927. doi: 10.1345/aph.1G248
523. McGonigle R, Woods RA. Take my breath away: a case of lactic acidosis in an asthma exacerbation. *CJEM*. 2011;13:284–288. doi: 10.2310/8000.2011.110236
524. Patel B, Assad D, Wiemann C, Zughaib M. Repeated use of albuterol inhaler as a potential cause of takotsubo cardiomyopathy. *Am J Case Rep*. 2014;15:221–225. doi: 10.12659/AJCR.890388
525. Jerrard DA, Olshaker J, Welebob E, Caraballo V, Hooper F. Efficacy and safety of a rapid-sequence metaproterenol protocol in the treatment of acute adult asthma. *Am J Emerg Med*. 1995;13:392–395. doi: 10.1016/0735-6757(95)90121-3
526. Singletary EM, Zideman DA, De Buck ED, Chang WT, Jensen JL, Swain JM, Woodin JA, Blanchard IE, Herrington RA, Pellegrino JL, et al; First Aid Chapter Collaborators. Part 9: first aid: 2015 International Consensus on First Aid Science With Treatment Recommendations. *Circulation*. 2015;132(suppl 1):S269–S311. doi: 10.1161/CIR.0000000000000278