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Part 3: Adult basic life support and automated external defibrillation 2015 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations☆

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Introduction

This Part of the *2015 International Consensus on Cardiopulmonary Resuscitation* (CPR) and *Emergency Cardiovascular Care* (ECC) *Science With Treatment Recommendations* (CoSTR) presents the consensus on science and treatment recommendations for adult basic life support (BLS) and automated external defibrillation (AED). After the publication of the 2010 CoSTR, the Adult BLS Task Force developed review questions in PICO (population, intervention, comparator, outcome) format.[1] This resulted in the generation of 36 PICO questions for systematic reviews. The task force discussed the topics and then voted to prioritize the most important questions to be tackled in 2015. From the pool of 36 questions, 14 were rated low priority and were deferred from this round of evidence evaluation. Two new questions were submitted by task force members, and 1 was submitted via the public portal. Two of these (BLS 856, and BLS 891) were taken forward for evidence review. The third question (368: Foreign-Body Airway Obstruction) was deferred after a preliminary review of the evidence failed to identify compelling evidence that would alter the treatment recommendations made when the topic was last reviewed in 2005.[2]

Each task force performed a systematic review using detailed inclusion and exclusion criteria, based on the recommendations of the Institute of Medicine of the National Academies.[3] With the assistance of information specialists, a detailed search for relevant articles was performed in each of 3 online databases (PubMed, Embase, and the Cochrane Library).

Reviewers were unable to identify any relevant evidence for 3 questions (BLS 811, BLS 373, and BLS 348), and the evidence review was not completed in time for a further question (BLS 370). A revised PICO question was developed for the opioid question (BLS 891). The task force reviewed 23 PICO questions for the 2015 consensus on science and treatment recommendations, including BLS 811, BLS 373, and BLS 348. The PICO flow is summarized in Fig. 1

Using the methodological approach proposed by the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) Working Group,[4] the reviewers for each question created a reconciled risk-of-bias assessment for each of the included studies, using state-of-the-art tools: Cochrane for randomized controlled trials (RCTs),[5] Quality Assessment of Diagnostic Accuracy Studies (QUADAS)-2 for studies of diagnostic accuracy,[6] and GRADE for observational studies that inform both therapy and prognosis questions.[7] GRADE evidence profile tables[8] were then created to facilitate an evaluation of the evidence in support of each of the

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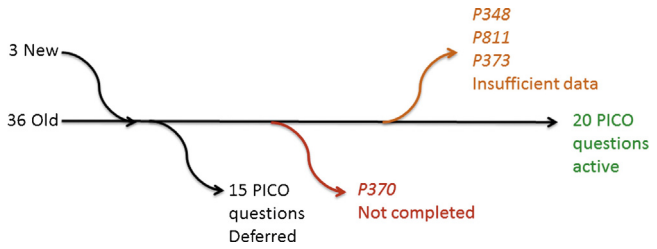

Fig. 1. Flow of PICO questions in the BLS task force.

critical and important outcomes. Critical outcomes were defined as neurologically favorable outcome (level 9), survival (level 8), and return of spontaneous circulation (ROSC; level 7). Given the heterogeneity of time points evaluated in the studies related to BLS/AED, time intervals were pooled across outcomes. For neurologic outcome and survival, we considered the outcomes at discharge, 30 days, 60 days, 180 days, and/or 1 year. Important outcomes included physiologic and process end points.

The quality of the evidence (or confidence in the estimate of the effect) was categorized as high, moderate, low, or very low,[9] based on the study methodologies and the 5 core GRADE domains of risk of bias, inconsistency, indirectness, imprecision, and other considerations (including publication bias).[10] These evidence profile tables were then used to create a written summary of evidence for each outcome (the consensus on science statements). Whenever possible, consensus-based treatment recommendations were then created. These recommendations (designated as strong or weak) were accompanied by an overall assessment of the evidence and a statement from the task force about the values and preferences that underlie the recommendations. A strong recommendation typically contains the words "we recommend," while a weak recommendation contains the words "we suggest." Further details of the methodology that underpinned the evidence evaluation process are found in "Part 2: Evidence Evaluation and Management of Conflicts of Interest."

The body of knowledge encompassed in this CoSTR comprises 23 individual systematic reviews with 32 treatment recommendations, derived from a GRADE evaluation of 27 randomized clinical trials and 181 observational studies of variable design and quality conducted over a 35-year period. The treatment recommendations in this Part are limited to recommendations for adults. Where there is overlap with pediatric topics, readers are referred to "Part 6: Pediatric Basic Life Support and Pediatric Advanced Life Support."

The actions linking the victim of sudden cardiac arrest with survival are called the Chain of Survival and form the order of presentation of the systematic reviews in this publication, as follows:

Early Access and Cardiac Arrest Prevention

- Dispatcher recognition of cardiac arrest (BLS 740)
- Dispatcher instruction (BLS 359)
- Resuscitation care for suspected opioid-associated emergencies (BLS 811)
- Opioid overdose response education (BLS 891)
- Drowning (BLS 856)

Early, High-Quality CPR

- Starting CPR (BLS 661)
- Chest compression-only CPR vs conventional CPR (BLS 372)
- CPR before defibrillation (BLS 363)
- Hand position during compressions (BLS 357)
- Chest compression rate (BLS 343)
- Chest compression depth (BLS 366)
- Chest wall recoil (BLS 367)
- Minimizing pauses in chest compressions (BLS 358)
- Compression-ventilation ratio (BLS 362)
- Timing of CPR cycles (BLS 346)
- Check for circulation during BLS (BLS 348)
- Feedback for CPR quality (BLS 361)
- EMS chest compression-only versus conventional CPR (BLS 360)
- Passive ventilation technique (BLS 352)
- Harm from CPR to victims not in cardiac arrest (BLS 353)

Early defibrillation

- Public-access defibrillation (BLS 347)
- Rhythm check timing (BLS 345)
- Analysis of rhythm during chest compression (BLS 373)

Early access and cardiac arrest prevention

Early access: emergency medical dispatch

The first contact with emergency medical services (EMS) is usually via a 9-1-1 or 1-1-2 emergency call. The correct and timely identification of cardiac arrest is critical to ensuring (1) the appropriate dispatch of a high-priority response, (2) the provision of telephone CPR instructions, and (3) the activation of community first responders carrying AEDs. In an observational study in the Netherlands, cases of cardiac arrest that were missed at initial telephone triage had much worse outcomes, 5% survival versus 14%.[11] Optimizing EMS dispatch is likely to be one of the most cost-effective solutions to improving outcomes from cardiac arrest. Thus, optimizing the ability of dispatchers to identify cardiac arrest and deliver telephone CPR instructions is critical to improving outcomes.

Dispatcher recognition of cardiac arrest (BLS 740)

Among adults and children who are in cardiac arrest outside of a hospital (P), does the description of any specific symptoms to the dispatcher (I), compared with the absence of any specific description (C), change the likelihood of cardiac arrest recognition (O)?

Consensus on science

For the critical outcome of **cardiac arrest recognition**, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from 1 cluster RCT,[12] as well as very-low-quality evidence from 26 non-RCTs comprising 8 before–after observational studies,[13–20] 9 prospective single-arm observational studies,[13,21–28] 8 retrospective single-arm observational studies,[29–36] and 1 case–control study.[11] A total of 17 420 patients were included in these 27 studies.

"Cardiac arrest recognition" was reported heterogeneously across the included studies, precluding meta-analysis. Seven observational studies reported the sensitivity of dispatch protocols to recognize cardiac arrest,[17,18,21,29–32] with results that ranged from 38% to 96.9% and specificity that exceeded 99% in the 2 studies that reported this outcome.[29,30] Recognition rates of cardiac arrest ranged from 18% to 83% where reported.[22,25]

The majority of the study dispatch centers used scripted dispatch protocols with questions to identify patients who are unconscious and not breathing or not breathing normally. Four before–after studies[16–18,20] suggested that introducing scripted dispatch protocols or modifying existing protocols can help increase cardiac arrest recognition. One study reported an increase in cardiac arrest recognition[16] while 3 reported an increase in the rates of telephone-assisted CPR after the introduction of scripted

dispatch protocols.[17,18,20] One study also reported an increase in "high-acuity" calls after a modification to the seizure protocol.[19]

Recognition of unconsciousness with abnormal breathing is central to dispatcher recognition of cardiac arrest. Many terms may be used by callers to describe abnormal breathing: difficulty breathing, poorly breathing, gasping breathing, wheezing breathing, impaired breathing,[22] occasional breathing, barely/hardly breathing, heavy breathing, labored or noisy breathing, sighing, and strange breathing.[11] Agonal breaths were reported in approximately 30% of cases in 1 study,[13] which can make obtaining an accurate description of the patient's breathing pattern challenging for dispatchers. The presence of agonal breaths were mentioned as a factor negatively affecting cardiac arrest recognition in 10 studies,[13–15,18,22,23,25,33,35,37] with 1 study reporting that agonal breaths were present in 50% of nonidentified cardiac arrest calls.[18] Other terms reported in the studies that may help identify possible cardiac arrest cases include "dead," "is dead," "cold and stiff," "blue," "gray," or "pale."[27] The aforementioned descriptions, however, may be limited, owing to cultural influences and language translation limitations.

Three before–after studies suggested that offering dispatchers additional education that specifically addresses agonal breaths can increase the rates of telephone-assisted CPR[14,15] and decrease the number of missed cases.[37]

There is evidence from 3 studies that failure to recognize cardiac arrest may be associated with failure to follow scripted protocols by omitting specified questions about consciousness and breathing.[23,24,26]

Treatment recommendation

We recommend that dispatchers determine if a patient is unconscious with abnormal breathing. If the victim is unconscious with abnormal or absent breathing, it is reasonable to assume that the patient is in cardiac arrest at the time of the call (strong recommendation, very-low-quality evidence).

We recommend that dispatchers be educated to identify unconsciousness with abnormal breathing. This education should include recognition and significance of agonal breaths across a range of clinical presentations and descriptions (strong recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making these recommendations, we placed a higher value on the recognition of cardiac arrest by dispatchers, and we placed a lower value on the potential harms arising from inappropriate CPR and the potential need for increased resources. In this situation, we believe that the benefits associated with increased numbers of cardiac arrest patients receiving timely and appropriate interventions outweigh the undesirable effects (potential for patients not in cardiac arrest to inappropriately receive chest compressions, potential need for increased resources).

We recognize that the evidence in support of these recommendations comes from mainly observational studies of very low quality. Large, high-quality RCTs addressing this question are unlikely to be conducted. We believe that the available evidence shows consistent results favoring scripted dispatch protocols and that education including a description of the presenting signs of cardiac arrest and populations at risk (e.g., patients presenting with seizures) enables dispatchers to identify cardiac arrest. We recognize that dispatch protocols for a range of conditions (including but not limited to "seizures," "breathing problems," "chest pains," "falls," and "unknown problem") optimized to identify potential cardiac arrest without undue delay may further improve early recognition of cardiac arrest.

Knowledge gaps

High-quality data from RCTs are currently lacking. Further studies are required to determine the following:

- What are the identifying key words used by callers that are associated with cardiac arrest?
- Should there be "trigger" words or phrases from the bystander that are so likely to indicate cardiac arrest that the dispatcher can skip parts of the protocol and shorten the time to dispatch and to CPR instruction?
- What is the impact of adherence to or failure to follow dispatch protocols?
- What is the most appropriate educational content to ensure that dispatchers are able to recognize the significance of abnormal and agonal breaths?
- What is the most appropriate refresher training interval for dispatchers?
- Is there a difference in recognition rates between dispatchers with a clinical background and those without a clinical background?

Dispatcher instructions (BLS 359)

Among adults and children who are in cardiac arrest outside of a hospital (P), does the ability of a dispatch system to provide CPR instructions (I), compared with a dispatch system where no CPR instructions are ever provided (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; delivery of bystander CPR; time to first shock; time to commence CPR; CPR parameters (O)?

Introduction

Bystander CPR rates remain relatively low in most communities. Dispatcher-assisted telephone CPR instructions have been demonstrated to improve bystander CPR rates.

This review identified 1 meta-analysis,[38] 3 randomized trials,[39–41] and 11 observational studies.[15,17,18,20,27,34,42–46] The population evaluated in most studies were adults with a presumed cardiac cause of their cardiac arrest and excluded traumatic and/or asphyxial causes of cardiac arrest.[17,20,42,44,41] Two studies evaluated all out-of-hospital arrests,[15,34] although benefit was limited to the cardiac cause subgroup in 1 of these studies.[15] Two studies evaluated telephone-assisted CPR in children.[45,46]

Some studies evaluated the survival benefit of dispatch-assisted CPR instructions and compared systems where such instructions can be offered to systems where they were never or infrequently offered.[15,17,18,20,27,34,43–45] Other studies compared traditional CPR to chest compression-only CPR instructions delivered by telephone.[39–42]

Consensus on science

For the critical outcome of **survival with favorable neurologic outcome**, we have identified very-low-quality evidence from 2 RCTs,[39,40] 2 cohort studies,[45,46] and 1 before–after study.[15] The level of evidence was downgraded for risk of bias, indirectness, and imprecision. Four studies reported no benefit in neurologic outcomes.[39,45,46,40] The before–after study, which included dispatcher instructions to start compression-only CPR as part of a bundle of interventions used as part of a quality improvement initiative, noted improved neurologic outcomes at 12 months (odds ratio [OR], 1.81; 95% confidence interval [CI], 1.2–2.76).[15]

For the critical outcome of **survival**, we identified very-low-quality evidence from 3 RCTs.[39–41] The level of evidence was downgraded for risk of bias, indirectness, and imprecision. Meta-analysis of these trials found an absolute survival benefit of 2.4%

(95% CI, 0.1%–4.9%) in favor of telephone-assisted continuous chest compressions over telephone-assisted traditional CPR (number needed to treat [NNT], 41; 95% CI, 20–1250; relative risk [RR], 1.22; 95% CI, 1.01–1.46).[38]

We also identified 6 before–after studies.[15,17,18,20,42,43] One study was inconsistent with the others and found decreased survival, although it was not powered to evaluate survival outcomes.[18] One study showed a survival benefit at 1 year (population of 73 patients) from an educational program for dispatchers on continuous chest compressions and agonal breaths (adjusted OR, 1.81; 95% CI, 1.20–2.76).[15]

We also identified 5 cohort studies.[27,34,44–46] One study showed a survival benefit at 30 days when, after an educational program, telephone-assisted CPR was provided to a pediatric out-of-hospital cardiac arrest (OHCA) population versus not (adjusted OR, 1.46; 95% CI, 1.05–2.03).[45] A second cohort study in the pediatric (less than 18 years of age) population showed survival benefit at 30 days when telephone-assisted CPR was provided (adjusted OR for group not receiving CPR, 0.70; 95% CI, 0.56–0.88).[46]

For the critical outcome of **ROSC**, we identified very-low-quality evidence from 1 RCT[40] and 1 before–after study.[18] The studies were downgraded for indirectness and imprecision. Neither study showed a statistically significant benefit.

For the important outcome of **delivery of bystander CPR**, we identified very-low-quality evidence from 6 before–after studies: 1 study compared 2 medical priority dispatch system versions,[42] 3 studies compared telephone-assisted CPR versus not,[17,18,43] and 2 studies[15,20] compared various educational programs. In addition, we identified 1 cohort study.[45] The level of evidence was downgraded for indirectness and imprecision. All showed a strong association between telephone-assisted CPR and bystander CPR. The cohort study showed increased performed chest compressions (adjusted OR, 6.04; 95% CI, 4.72–7.72) and ventilation (adjusted OR, 3.10; 95% CI, 2.44–3.95) from telephone-assisted CPR, and an absolute increase in bystander CPR rate of 40.9% (95% CI, 36.1–45.5).[45]

For the important outcome of **time to commence CPR**, we have identified very-low-quality evidence from 4 before–after studies[15,17,20,43] and 1 cohort study.[44] The level of evidence was downgraded for risk of bias, inconsistency, indirectness, and imprecision. None of these reported a statistically significant benefit.

For the important outcome of **CPR parameter**, assessed with initial rhythm of ventricular fibrillation (VF)/pulseless ventricular tachycardia (PVT), we have identified very-low-quality evidence from 1 RCT[41] and 1 before–after study.[18] The studies were downgraded for risk of bias, indirectness, and imprecision. Neither study showed a statistically significant benefit.

Treatment recommendation

We recommend that dispatchers provide chest compression-only CPR instructions to callers for adults with suspected OHCA (strong recommendation, low-quality evidence).

Values, preferences, and task force insights

In making these recommendations, we placed a higher value on the initiation of bystander CPR and a lower value on the harms of performing CPR on patients who are not in cardiac arrest. We recognize that the evidence in support of these recommendations comes from randomized trials and observational data of variable quality. However, the available evidence consistently favors telephone CPR protocols that use a compression-only CPR instruction set, suggesting a dose effect—that is, quick telephone instructions in chest compressions result in more compressions and faster administration of CPR to the patient.

Knowledge gaps

- What is the optimal instruction sequence for coaching callers in telephone-assisted CPR?
- What is the impact of telephone CPR instructions on noncardiac etiology arrests in adult and pediatric patients?
- What is the impact of the dispatchers' background (non-healthcare professional versus paramedic or nurse)?
- What are the time-interval benchmarks for the completion of each step in the instruction process (transfer to ambulance dispatch, cardiac arrest recognition, dispatch of resources, initiation of instructions, etc.)?
- What is the benefit or role in the use of an AED locator or enhanced citizen response or "dual-dispatch" system?
- What is the impact of language barriers to performance?
- What are the best methods to optimize initial training methodology, retraining frequency interval, and quality improvement programs for optimal dispatcher performance and effectiveness?
- What is the optimal system approach to provide instructions to the highest number of cardiac arrest patients?
- How many chest compressions should be given, and for how long, before ventilation instructions are introduced?

Resuscitation care for suspected opioid-associated emergencies (BLS 811)

In adults and children with suspected opioid-associated cardio/respiratory arrest in the prehospital setting (P), does bystander naloxone administration (intramuscular or intranasal), in addition to conventional CPR (I), compared with conventional CPR only (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC (O)?

Introduction

Opioid overdose is a leading cause of death in many communities and at-risk populations. With widespread implementation of community naloxone distribution programs, there is a need for evaluating the evidence of such initiatives to provide guidance for policy makers.

Consensus on science

We did not identify any published studies to determine if adding intranasal or intramuscular naloxone to conventional CPR is superior to conventional CPR alone for the management of adults and children with suspected opioid-associated cardiac or respiratory arrest in the prehospital setting. An additional search was performed to assess available evidence for overdose education and naloxone distribution programs (see BLS 891).

Treatment recommendation

No treatment recommendation can be made for adding naloxone to existing BLS practices for the BLS management of adults and children with suspected opioid-associated cardiac or respiratory arrest in the prehospital setting.

Values, preferences, and task force insights

All patients with suspected opioid-associated cardiac or respiratory arrest should receive standard BLS care, with or without the addition of naloxone. In making this recommendation, we place greater value on the potential for lives saved by recommending immediate BLS care and education, with or without naloxone, and lesser value on the costs associated with naloxone administration, distribution, or education.

Knowledge gaps

- Further research is needed to determine the optimal components of overdose response education for BLS and first aid providers, the role of naloxone, and how these educational programs should be implemented and evaluated.

Opioid overdose response education (BLS 891)

In adults and children at risk of suspected cardio/respiratory arrest due to opioids in the prehospital setting (P), does opioid overdose response education, with or without naloxone distribution (I), compared with no overdose response education or overdose prevention education only (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC (O)?

Introduction

Opioid overdose events have increased dramatically and become a leading cause of premature, preventable mortality in many communities. With widespread implementation of various community programs, there is a need for evaluating the evidence of such initiatives to provide guidance for policy makers.

Consensus on science

For the critical outcome of **survival to hospital discharge**, we have identified very-low-quality evidence (downgraded for risk bias, inconsistency, indirectness, and imprecision) from 3 observational before–after studies.[47,48] Only 1 of 3 studies[49] attempted to correct for any confounding factors expected in interventional studies by using historic controls. This study did observe a dose-response gradient with 0.73 (95% CI, 0.57–0.91) and 0.54 (95% CI, 0.39–0.76) adjusted-rate ratios for lethal overdose in communities with low and high implementation, respectively.[49] The remaining 2 observational studies reported reductions in rate ratios for lethal overdose in communities, 0.62 (95% CI, 0.54–0.72)[50] and 0.70 (95% CI, 0.65–0.74).[47]

Treatment recommendation

We suggest offering opioid overdose response education, with or without naloxone distribution, to persons at risk for opioid overdose in any setting (weak recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making these recommendations, we place greater value on the potential for lives saved by recommending overdose response education, with or without naloxone, and lesser value on the costs associated with naloxone administration, distribution, or education.

Knowledge gaps

- Further research is needed to determine the optimal components of opioid overdose response education, the role of naloxone, and how these educational programs should be implemented and evaluated.

Drowning search and rescue (BLS 856)

In adults and children who are submerged in water (P), does any particular factor in search-and-rescue operations (e.g., duration of submersion, salinity of water, water temperature, age of victim) (I), compared with no factors (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC (O)?

Introduction

This question was initiated in response to a request that ILCOR review the evidence for prognostic factors that predict outcome in relation to a drowning incident. Drowning is the third leading cause of unintentional injury death worldwide, accounting for nearly 400 000 deaths annually. Care of a submersion victim in high-income countries often involves a multiagency approach, with several different organizations being independently responsible for different phases of the victim's care, from the initial aquatic rescue, on-scene resuscitation, transfer to hospital, and hospital and rehabilitative care. Attempting to rescue a submerged victim has substantial resource implications and may place rescuers at risk themselves.

The systematic review included observational studies with control groups, which presented data enabling us to calculate RRs or reported ORs for the following prognostic factors: (1) age, (2) EMS response time, (3) salinity, (4) submersion duration, and (5) water temperature. The review excluded single case reports and case series less than 5 or without comparator groups. Full details of the search strategy and included articles are summarized in Scientific Evidence Evaluation and Review System (SEERS). It is worth highlighting that, in accordance with GRADE guidelines for prognostic studies, evidence from observational studies starts as high. In reviewing the summaries of evidence, one should note that the studies reviewed extended over a 30-year period. It is possible that outcomes may have changed over time, although this was not observed in the 2 studies that evaluated outcomes over time.[51,52] The populations evaluated varied between studies and included emergency service data, coroners' registries, emergency department, and intensive care admissions.

Consensus on science

Age. For the critical outcome of **favorable neurologic outcome**, we identified very-low-quality evidence from 11 observational studies (downgraded for risk of bias inconsistency, indirectness, and imprecision) comprising 4054 patients.[51,53–62] Of the 7 pediatric studies, 6 found that young age, variably defined as less than 3, 4, 5, or 6 years, was not associated with favorable neurologic outcome.[53–57,59] A single pediatric study including 166 children aged less than 15 years reported better outcomes in children aged less than 5 years (RR, 0.12; 95% CI, 0.03–0.44).[58]

Four studies considered drowning victims of all ages; 3 found no relationship between age and outcome.[60–62] One reported worse outcomes among children aged greater than 5 years (RR, 0.66; 95% CI, 0.51–0.85).[51]

For the critical outcome of **survival**, we identified very-low-quality evidence (downgraded for risk of bias, inconsistency, indirectness, and imprecision) from 6 observational studies, which included 1313 patients.[63–68] Three studies found that age was not associated with outcome.[64,66,68] Two showed better outcomes associated with younger ages (less than 58 years: RR, 0.27; 95% CI, 0.08–0.96[65]; less than 46 years: RR, 0.98; 95% CI, 0.99–0.99),[67] and 1 favored older age (3 years or older: RR, 1.51; 95% CI, 1.19–1.9).[63]

EMS response interval. No studies were identified that addressed the critical outcome of favorable neurologic outcome.

For the critical outcome of **survival**, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from 2 observational studies, including 746 patients in the Swedish EMS OHCA registry.[65,69] EMS response intervals of

less than 10 min were associated with better survival: RR of 0.29 (95% CI, 0.13–0.66)[69] and reported OR of 0.44 (95% CI, 0.06–0.83).[65]

Salinity. For the critical outcome of **favorable neurologic outcome**, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from 4 observational studies,[51,57,61,70] which included 1842 drowning victims, of which 370 occurred in salt water and 1427 in fresh water. Two showed salt water was associated with better outcomes (RR, 1.3; 95% CI, 1.12–1.5[61]; RR, 1.2; 95% CI, 1.1–1.4[57]), and 2 showed water type was not associated with outcome (RR, 1.1; 95% CI, 0.95–1.2[70]; RR, 1.14; 95% CI, 0.9–1.4[51]).

For the critical outcome of **survival**, we identified very-low-quality evidence (downgraded for risk of bias imprecision, inconsistency, indirectness, and imprecision) from 3 studies.[63,66,71] One reported better outcomes for salt water (RR, 1.34; 95% CI, 1.19–1.52),[71] 1 showed no difference (RR, 1.22; 95% CI, 0.95–1.56),[63] and 1 showed worse survival in cases with salt water drowning (RR, 0.18; 95% CI, 0.03–1.43).[66]

Submersion duration. For the purposes of this review, we considered studies in 3 groups. We defined those with short submersion intervals (less than 5–6 min), those with intermediate duration (less than 10 min), and those with prolonged submersion intervals (less than 20–25 min).

Short submersion intervals (less than 5–6 min). For the critical outcome of **favorable neurologic outcome**, we identified moderate-quality evidence from 12 observational studies (downgraded for bias and indirectness, upgraded for dose-response gradient), which included 2409 cases.[51–53,55–59,62,72–74] All studies noted worse outcomes among patients with submersion durations exceeding 5 min (RRs ranged between 0.05[51] and 0.61[58]). The 713/826 patients (86.3%) who had outcome information available and were submerged for short durations had good outcomes compared to 128/1150 (11%) with longer submersion durations.

For the critical outcome of **survival**, we identified low-quality evidence (downgraded for risk of bias, indirectness, and imprecision; upgraded for dose-response gradient) from 5 observational studies comprising 317 cases.[63,64,71,75,76] All studies noted worse outcomes among patients with prolonged compared to short submersion durations (RRs ranged between 0.27[75] and 0.83[76]). The 159/170 patients (93.5%) submerged for short durations had good outcomes compared to 45/84 (53%) with longer submersion durations.

Intermediate submersion intervals (less than 10 min). For the critical outcome of **favorable neurologic outcome**, we identified moderate-quality evidence (downgraded for bias, indirectness, and imprecision; upgraded for dose-response gradient) from 9 observational studies that included 2453 cases.[51,52,55,57,58,72,73,77,78] All studies noted worse outcomes among patients with prolonged submersion durations compared with intermediate submersion durations (RRs ranged between 0.02[51] and 0.45[58,73]). The 787/1019 patients (77.2%) submerged for intermediate durations had good outcomes compared to the 36/962 (3.7%) with longer submersion durations.

For the critical outcome of **survival**, we identified low-quality evidence (downgraded for bias, indirectness, and imprecision; upgraded for dose-response gradient) from 2 observational studies[71,79] comprising 121 cases. The first study[71] reported 56/73 (77%) of those submerged for less than 10 min survived compared with none of the 7 patients who were submerged for more prolonged periods survived (RR not estimable; absolute difference, 76.7%; 39.7–94.9%). The second study[79] also noted better survival among those submerged for less than 10 min (46/50 [96%] survived) compared with those submerged for more than 10 min (2/5 [40%] survived).[79]

Prolonged submersion intervals (less than 15–25 min). For the critical outcome of **favorable neurologic outcome**, we identified low-quality evidence (downgraded for risk of bias and imprecision, upgraded for dose-response gradient) from 3 observational studies that included 739 cases.[52,55,57] In 1 study ($n = 398$),[57] submersion less than 20 min was associated with improved survival (289/370 [78%] good outcome versus 1/27 [4%] good outcome; RR, 0.05; 95% CI, 0.01–0.31). The second study[55] reported better outcomes if submersion duration was less than 25 min (68/101, or 67%) versus submersion duration longer than 25 min (0/4, 0%). The third study, which included hypothermic children in cardiac arrest, observed 12/66 (18%) survivors who were submerged for less than 25 min compared with 0/39 who were submerged for more than 25 min.[52]

For the critical outcome of **survival**, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from a single study[75] comprising 49 patients. Cases with a submersion interval of less than 15 min had an overall survival rate of 82% (33/39) compared with none of the 2 victims whose submersion duration exceeded 15 min (RR not estimable; absolute difference, 84.6% [17.3%–92.8%]).

Water temperature. For the critical outcome of **favorable neurologic outcome**, we identified very-low-quality evidence (downgraded for risk bias, inconsistency, indirectness, and imprecision) from 2 studies[51,52] of 1254 cases. The largest study ($n = 1094$) included all unintentional drownings in open waters (lakes, ponds, rivers, ocean) in a single large region, collected from medical examiners, EMS systems, and all regional hospitals.[51] Water temperatures were measured within a month of the drowning incident. Univariate analysis according to temperatures less than or greater than 6 °C or less than or greater than 16 °C found no difference in neurologic survival: RR, 1.11 (95% CI, 0.9–1.37); RR, 1.02 (95% CI, 0.81–1.27); absolute difference, −0.5% (−7.5% to 6.1%), respectively. Multivariate analysis also showed that water temperature was not associated with outcome. The second study included 160 hypothermic children who required resuscitation after submersion. Water temperatures were estimated based on the season. Submersion in the winter (water temperature estimated as 0–8 °C) was associated with better outcomes than submersion in spring or summer (water temperature 6–28 °C) (univariate OR, 4.55; 95% CI, 1.37–15.09).

For the critical outcome of **survival**, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from a single study[65] that included 250 patients. This study included only drowning victims who had an OHCA and received EMS care, and it included those with intentional (suicide and homicide) drowning. This study showed no relationship between water temperature less than or greater than 15 °C and outcome (RR, 0.94; 95% CI, 0.34–2.62; absolute difference, 0.36%, −6.4% to 6.5%).

Witnessed status. The definition of witnessed versus unwitnessed was inconsistently defined in the studies reviewed. It was often unclear if witnessed related to the submersion or time of cardiac arrest.

For the critical outcome of **favorable neurologic outcome**, we found very-low-quality evidence (downgraded for indirectness and imprecision) from 1 observational study[60] involving 1737 patients. Univariate analysis reported by the study authors indicates an unadjusted OR for good outcomes in the group where submersion was witnessed (OR, 16.33; 95% CI, 5.58–47.77). In multivariate analysis, witnessed status was related to favorable outcome (adjusted OR, 11.8; 95% CI, 2.84–49.08); however, the analysis did not include submersion duration, which several studies have reported is an independent predictor.

For the critical outcome of **survival**, we found low-quality evidence (downgraded for risk of bias, indirectness, and imprecision)

from 4 studies[60,66,67,69] involving a total of 2857 victims. Two studies[65,67] were from the same EMS system, and both used multivariate analysis. The smaller study (255 victims) showed that witnessed status was not significantly associated with improved survival (RR, 0.55; 95% CI, 0.17–1.75; absolute difference, 3%; −3.1% to 11.2%).[65] However, in the larger subsequent study from that same EMS system, witnessed status predicted better outcome (reported univariate analysis $P = 0.05$; adjusted OR, 2.5; 95% CI, 1.38–4.52).[67] A further study[66] showed no association of witnessed status with improved survival (RR, 0.82; 95% CI, 0.26–2.59). A large observational study from Japan[60] reported an unadjusted OR of 7.38 (95% CI, 3.81–14.3) and an adjusted OR of 6.5 (95% CI, 2.81–15.02), although the unusual population of much older victims, most drowning in bathtubs, with very low favorable outcomes limited the generalizability of these findings.

Treatment recommendations

We recommend that submersion duration be used as a prognostic indicator when making decisions surrounding search and rescue resource management/operations (strong recommendation, moderate-quality evidence for prognostic significance).

We suggest against the use of age, EMS response time, water type (fresh or salt), water temperature, and witness status when making prognostic decisions (weak recommendation, very-low-quality evidence for prognostic significance).

We acknowledge that this review excluded exceptional and rare case reports that identify good outcomes after prolonged submersion in icy cold water.

Values, preferences, and task force insights

In making these recommendations, the task force placed priority on producing simple guidance that may assist those responsible for managing search and rescue operations. The public comments highlighted the difficult moral dilemmas facing the rescuer in these often emotionally charged and fast-moving environments. While it is hoped that the information will also be of interest to those managing the initial resuscitation and intensive care treatment of drowning victims, the factors evaluated were limited to those available at the scene of the drowning incident and excluded factors available after the victim was rescued (e.g., patient regurgitation, cardiopulmonary arrest duration, EMS response time, CPR duration, hospitalization[80,81]).

The recommendations presented place a relatively high value on the associations demonstrated in the exploratory prognostication modeling but acknowledge that these have not been prospectively validated as clinical decision rules. Submersion durations of less than 10 min are associated with a very high chance of favorable outcome, and submersion durations more than 25 min are associated with a low chance of favorable outcomes. Given the known difficulties with accurate timing, we suggest the time of the emergency service call as the start point for estimating submersion duration.

This question raised significant debate during the plenary conference session, task force discussion, and public comment. The main areas of controversy related to (1) how ILCOR intended the information presented would be used, and (2) the prognostic value of water temperature. We clarified in the introduction to this section that the review is intended to provide evidence from the published literature to support those responsible for search-and-rescue operations about chances of survival.

In recommending submersion duration as a factor, we acknowledge that definitions of submersion were either absent or varied between studies, and, in many studies, the precise submersion duration was not known. The 2015 Utstein consensus on drowning defines submersion duration as the duration of time that liquid covering the nose and mouth prevents air from entering the lungs.[82] We suggest that the studies are interpreted as assuming the point from which continuous submersion started (i.e., not when the person is struggling and intermittently submerging then drawing breath). Because the underwater interval is seldom documented with a timepiece, estimates can be imprecise. The Utstein consensus recommended cross-referencing submersion point with the emergency call and ambulance arrival times when possible.

The scope of this systematic review was limited to large case series and cohort studies with control groups. The review, therefore, excluded rare and exceptional case reports of survival after prolonged submersion in ice-cold water. One such example is the series of case reports presented by Tipton and Golden, which identified 26 survivors after submersion, 8 reports documented favorable outcomes in victims submerged for longer than 25 min in mostly ice-cold water.[83] A further case series noted 80% of victims surviving after cardiac arrest after immersion in ice-cold water (2 °C) for up to 2.5 h.[84] This review included more than 1000 drowning victims and produced conflicting results on the role of water temperature. Both studies noted difficulty in estimating water temperature, which is likely to be reflected in real-life rescue situations. Thus, a combination of uncertainty in the published evidence and practical difficulties of measurement led us to suggest against the routine use of water temperature as a prognostic factor.

The task force is very grateful for insightful comments submitted during the public commenting process.

High-quality CPR

Early high-quality CPR saves lives. This section reviews the evidence surrounding how to start CPR, as well as optimal chest compression characteristics, compression-only CPR, pulse checks, and ventilation. Although the systematic reviews considered adult and pediatric data, treatment recommendations in this Part are limited to adult patients. The reader is referred to "Part 6: Pediatric Basic Life Support and Pediatric Advanced Life Support" for related pediatric recommendations.

In making these recommendations, we note that several components of chest compressions can alter their effectiveness: hand position, position of the rescuer, position of the victim, and depth and rate of compression and release. The relative importance of each of these components remains to be determined; thus, optimal chest compressions are defined by compressions of the correct position, depth, and rate, ensuring full release and minimizing interruptions.

Collectively, we continue to place strong emphasis on the importance of delivering high-quality CPR.

Starting CPR (BLS 661)

Among adults and children who are in cardiac arrest in any setting (P), does CPR beginning with compressions first (30:2) (I), compared with CPR beginning with ventilation first (2:30) (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC (O)?

Introduction

Delivering high-quality chest compressions as early as possible is vital to high-quality CPR and optimizes the chance of ROSC and survival after cardiac arrest. Thus, a major change after publication of the *2010 International Consensus on CPR and ECC Science With Treatment Recommendations* was the recommendation that, for adult victims of cardiac arrest, CPR should begin with giving chest compressions rather than opening the airway and delivering rescue breaths. This treatment recommendation is based on a

review of science from the perspective of developing a treatment recommendation for adults.

Consensus on science

There were no human studies identified in this evidence review, but 4 manikin studies were identified; 1 randomized study[85] focused on adult resuscitation, 1 randomized study focused on pediatric resuscitation,[86] and 2 observational studies focused on adult resuscitation.[87,88] Compared with the previous review in 2010, this review also identified 3 new studies that were included for analysis.[85,86,88] Overall, the reviewers had serious concerns for trial methodology of included studies. The nature of comparing 2 different resuscitation protocols meant that all studies suffered from performance and detection bias because healthcare professionals were not blinded to the intervention (C-A-B versus A-B-C).

For the important outcome of **time to commencement of chest compressions**, we identified very-low-quality evidence from 1 randomized manikin study[86] representing 155 two-person teams and very-low-quality evidence from 2 observational manikin studies[87,88] representing 40 individual rescuers[88] and 33 six-person teams.[87] All studies were downgraded due to risk of bias. All studies found that C-A-B decreased the time to commencement of chest compression. The randomized trial found a statistically significant 24.13-second difference ($P < 0.05$) in favor of C-A-B.[86] The observational studies found statistically significant decreases of 20.6 s ($P < 0.001$)[88] and 26 s ($P < 0.001$),[87] respectively.

For the important outcome of **time to commencement of rescue breaths**, we identified very-low-quality evidence from 2 randomized manikin studies[85,86] representing 210 two-person teams. Both studies were downgraded due to risk of bias. Lubrano[86] found a statistically significant 3.53-s difference ($P < 0.05$) in favor of C-A-B during a respiratory arrest scenario; however, in a cardiac arrest scenario, A-B-C decreased the time to commencement of rescue breaths by 5.74 s ($P < 0.05$).[85] Marsch found that C-A-B decreased time to commencement of rescue breaths by 5 s ($P = 0.003$). The clinical significance of these differences is unknown.[85]

For the important outcome of **time to completion of first CPR cycle** (30 chest compressions and 2 rescue breaths), we identified low-quality evidence from 1 randomized manikin study[85] representing 55 two-person teams. Marsch[85] found that C-A-B decreased time to completion of first CPR cycle by 15 s ($P < 0.001$). The clinical significance of this difference is unknown.

Treatment recommendation

We suggest commencing CPR with compressions rather than ventilations (weak recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making this recommendation in the absence of human data, we placed a high value on time to specific elements of CPR (chest compressions, rescue breathing, completion of first CPR cycle). In making this recommendation in the absence of human data, given that most cardiac arrests in adults are cardiac in cause, we placed a high value on reducing time to specific elements of CPR (chest compressions and completion of first CPR cycle).

We refer the reader to the systematic review Peds 709 (see "Part 6: Pediatric Basic Life Support and Pediatric Advanced Life Support") for recommendations in children.

Chest compression-only CPR versus conventional CPR (BLS 372)

Among adults who are in cardiac arrest outside of a hospital (P), does provision of chest compressions (without ventilation) by untrained/trained laypersons (I), compared with chest compressions with ventilation (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; bystander CPR performance; CPR quality (O)?

Introduction

Bystander CPR is a key life-saving factor in the Chain of Survival. This foundational principle was evaluated in the ILCOR 2000 Consensus on Science and was accepted in the 2005, 2010, and 2015 consensuses without reevaluation. The review in 2000 found that CPR before EMS arrival can (1) prevent VF/pVT from deteriorating to asystole, (2) increase the chance of defibrillation, (3) contribute to preservation of heart and brain function, and (4) improve survival.[89] A large systematic review from 79 studies involving 142 740 patients confirmed that bystander CPR improves survival from 3.9% to 16.1%.[90]

Although the practice of bystander CPR is accepted, a key question is whether bystanders should perform chest compression-only CPR or conventional CPR. Advocates of chest compression-only CPR note that it is easier to teach, remember, and perform compared with chest compressions with assisted ventilation. Others are concerned that chest compressions without assisted ventilation are less effective because of inadequate oxygenation and worse respiratory acidosis. These concerns are especially pertinent in the setting of asphyxial cardiac arrests (and perhaps others with a non-cardiac cause) and in the setting of prolonged CPR.[91]

It is not feasible to conduct RCTs of bystander-initiated, compression-only CPR versus bystander conventional CPR. Therefore, the clinical evidence for this question is derived from 2 sources: observational studies, and RCTs of dispatcher-assisted CPR. The benefits of telephone-assisted CPR are summarized in our EMS dispatch question (see BLS 359).

Further, much of the research on this topic has been done on patients whose arrests are presumed to be of cardiac origin, which would be difficult, if not impossible, to coach bystanders to determine in a brief training session. In addition, the research was often conducted in settings with short EMS response intervals. It is likely that a time threshold exists beyond which the absence of ventilation may be harmful.[92,93] Thus, the generalizability of the findings from the studies to all settings is cautioned. These factors taken together mean that the data available for considering this question are indirect.

When observational studies are conducted for bystander CPR, a key factor in evaluating the data is determining how the investigator determined the type of bystander CPR that was performed. In some cases, providers stayed on the scene and interviewed the bystanders about the care they provided. However, in studies of registry data, EMS providers visually evaluated bystanders' actions as they took over care during this high-stress, high-risk, and time-intensive event. This issue led to many studies being downgraded for validity because determination of the type of bystander CPR may have been biased.

Consensus on science

For the critical outcome of **survival with favorable neurologic outcome at 12 months**, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from a single observational study of 1327 adult cardiac arrest victims of a presumed cardiac cause. The study reported no overall difference between compression-only and conventional CPR (OR, 0.98; 95% CI, 0.54–1.77).[92]

For the critical outcome of **survival with favorable neurologic outcome at 30 days**, we identified very-low-quality evidence (downgraded for risk of bias and indirectness) from 4 observational studies that enrolled 40 646 patients.[91,93–95] These studies reported no overall difference in outcomes.

For the critical outcome of **survival with favorable neurologic outcome at discharge**, we identified very-low-quality evidence (downgraded for risk of bias, inconsistency, and indirectness) from 1 randomized trial[40] and 3 observational studies.[96–98] The randomized trial enrolled 1268 patients and reported no difference in outcomes (OR, 1.25; 95% CI, 0.94–1.66). The observational studies enrolled 2195 patients and also found no overall differences between compression-only and conventional CPR.

For the critical outcome of **survival at 30 days**, we identified very-low-quality evidence (downgraded for risk of bias and indirectness) from 1 randomized trial[41] and 2 observational studies.[99,100] The randomized trial enrolled 1276 patients and found no difference in outcomes (OR, 1.24; 95% CI, 0.85–1.81).[41] The observational studies enrolled 11 444 patients, and found no overall difference between compression-only and conventional CPR.[99,100]

For the critical outcome of **survival at 14 days**, we identified very-low-quality evidence (downgraded for risk of bias and indirectness) from 1 observational study[101] enrolling 829 patients, which found no difference between compression-only and conventional CPR (OR, 0.76; 95% CI, 0.46–1.24).

For the critical outcome of **survival to discharge**, we identified very-low-quality evidence (downgraded for risk of bias, inconsistency, and indirectness) from 1 randomized trial[102] and 2 observational studies.[103,104] The randomized trial enrolled 520 patients and found no difference in outcomes (OR, 1.4; 95% CI, 0.88–2.22).[102] The observational studied enrolled 2486 patients and reported no difference between compression-only and conventional CPR.

Treatment recommendations

We recommend that chest compressions should be performed for all patients in cardiac arrest (strong recommendation, very-low-quality evidence).

We suggest that those who are trained and willing to give rescue breaths do so for all adult patients in cardiac arrest (weak recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making these recommendations, the task force strongly endorsed the 2010 ILCOR Consensus on Science that all rescuers should perform chest compressions for all patients in cardiac arrest.[105,106] We also highlight the 2015 dispatcher CPR recommendation that "dispatchers should provide chest compression-only CPR instructions to callers for adults with suspected OHCA."

The task force draws attention to the potential gains from the simplicity of teaching compression-only CPR.

The task force further acknowledges the potential additional benefits of conventional CPR when delivered by trained laypersons, particularly in settings where EMS response intervals are long and for asphyxial causes of cardiac arrest.

We refer the reader to Ped 414 systematic review (see "Part 6: Pediatric Basic Life Support and Pediatric Advanced Life Support") for recommendations in children.

CPR before defibrillation (BLS 363)

Among adults and children who are in VF or pulseless VT (pVT) in any setting (P), does a prolonged period of chest compressions before defibrillation (I), compared with a short period of chest compressions before defibrillation (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; rhythm control (O)?

Introduction

The optimal initial approach to a patient found in VF outside of the hospital has been unclear. Observational studies have supported a short period of CPR followed by early analysis of cardiac rhythm and administration of a shock, if indicated. Other studies support a longer period of CPR before administration of a shock.

Our literature review retained 13 articles. These included 5 RCTs,[107–111] 4 observational cohort studies,[112–115] 3 meta-analyses,[116–118] and 1 subgroup analysis of data reported in the RCT by Rea et al.[119] For the purposes of this evidence review, the GRADE table is limited to pooled data from the 5 RCTs. All of the studies were conducted in the out-of-hospital setting.

The intervention assessed was a short period of chest compressions before attempted defibrillation with a longer period of chest compressions, defined as between 90 and 180 s, before attempted defibrillation. In all of the RCTs reviewed, chest compressions were performed before initial analysis while the defibrillator equipment was being applied. The exact duration of this period was documented precisely in only 1 RCT[110] and was noted to be between 30 and 60 s.

Consensus on science

For the critical outcome of **survival to 1 year with favorable neurologic outcome** (Cerebral Performance Category [CPC] of 2 or less), we identified low-quality evidence (downgraded for bias and imprecision) from a single randomized trial that showed no benefit from a short period of CPR before shock delivery (OR, 1.18; 95% CI, 0.522–2.667).[111]

For the critical outcome of **survival to hospital discharge with favorable neurologic outcome** (defined as CPC score of 2 or less, modified Rankin Scale score of 3 or less), we identified low-quality evidence (downgraded for inconsistency and imprecision) from 4 RCTs that showed no benefit from a short period of CPR before shock delivery (OR, 0.95; 95% CI, 0.786–1.15).[107,109–111]

For the critical outcome of **survival to 1 year**, we identified low-quality evidence (downgraded for bias and imprecision) from 2 RCTs that showed no benefit from a short period of CPR before shock delivery (OR, 1.15; 95% CI, 0.625–2.115).[108,111]

For the critical outcome of **survival to hospital discharge**, we identified low-quality evidence (downgraded for bias and imprecision) from 4 RCTs that showed no benefit from a short period of CPR before shock delivery (OR, 1.095; 95% CI, 0.695–1.725).[107–109,111]

With respect to **ROSC**, we identified low-quality evidence (downgraded for bias and imprecision) from 4 RCTs that showed no benefit from a short period of CPR before shock delivery (OR, 1.193; 95% CI, 0.871–1.634).[107–109,111]

Subgroup analyses. Two subgroup analyses were also considered in this review. One subgroup analysis looked at enrollments based on EMS response interval, comparing those with intervals of less than 4–5 min versus those with intervals of 4–5 min or more. Within this subgroup, 1 study[111] found a favorable relationship with CPR for 180 s before defibrillation when the response interval was 5 min or more, but this relationship was not confirmed in 3 other RCTs.[107,108,110]

The second subgroup analysis[119] examined outcomes from early versus late analysis based on baseline EMS agency VF/pVT survival rates. Among EMS agencies with low baseline survival to hospital discharge (defined as less than 20% for an initial rhythm of VF/pVT), higher neurologically favorable survival was associated with early analysis and shock delivery, as opposed to CPR and delayed analysis and shock delivery. Yet for EMS agencies with higher baseline survival to hospital discharge (greater than 20%), 3 min of CPR followed by analysis and defibrillation resulted in higher neurologically favorable survival. Although no study has suggested harmful effects from up to 180 s of CPR before defibrillation, an exploratory

analysis from 1 RCT[110] suggested a decline in survival to hospital discharge from a prolonged period of CPR (180 s) with delayed shock delivery in patients with an initial rhythm of VF/pVT that had received bystander CPR, compared with a shorter period of CPR (30–60 s) followed by shock delivery.

Evidence summary. In summary, the evidence suggests that among unmonitored patients with cardiac arrest outside of the hospital and an initial rhythm of VF/pVT, there is no benefit to a period of CPR of 90–180 s before defibrillation when compared with immediate defibrillation with CPR being performed while the defibrillator equipment is being applied.

Treatment recommendation

During an unmonitored cardiac arrest, we suggest a short period of CPR until the defibrillator is ready for analysis and, if indicated, defibrillation.

Values, preferences, and task force insights

In making these recommendations, we placed a higher value on the delivery of early defibrillation and a lower value on the as-yet-unproven benefits of performing CPR for a longer period of time. We recognize that the evidence in support of these recommendations comes from randomized trials of variable quality conducted in several countries with a variety of EMS system configurations. The available evidence suggests a minimal effect size overall, while recognizing that it remains possible that, in systems with higher baseline survival rates, a longer period of CPR may be superior.

The task force notes that these recommendations apply to unmonitored victims in cardiac arrest. In witnessed, monitored VF/pVT arrest where a patient is attached to a defibrillator, shock delivery should not be delayed.

Knowledge gap

- What system level characteristics might influence adopted strategy?
- What effect does the quality of bystander CPR have?
- Can electrocardiographic waveform characteristics be used to determine optimal strategy?
- If CPR first strategy is adopted, what is the optimal duration of CPR (90 s, 120 s, or 180 s)?

Hand position during compressions (BLS 357)

Among adults and children who are receiving chest compressions in any setting (P), does delivery of chest compressions on the lower half of the sternum (I), compared with any other location for chest compressions (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; cardiac output; harm (e.g., rib fracture); coronary perfusion pressure (O)?

Introduction

Hand position is just one of several components of chest compressions that can alter effectiveness. In making this recommendation, we considered the evidence in an attempt to define the optimal compression method. We balanced this against the current recommendation for using the lower half of the sternum[105] and the resource implications of changing current recommendations.

The task force also noted previous recommendations that the lower half of the sternum could be identified by instructing a rescuer, "Place the heel of your hand in the center of the chest with the other hand on top."[120,121] This instruction should be accompanied by a demonstration of placing the hands on the lower half of the sternum.[121]

This review focused on studies reporting clinical or physiologic outcomes related to hand position during chest compression. The scope differed from the 2010 CoSTR review, which also included computed tomographic, echocardiographic, and manikin studies reporting on the anatomic structures that would be compressed with different hand positions and the efficiency of different instructional techniques for locating hand position.

Consensus on science

There were no studies reporting the critical outcomes of favorable neurologic outcome, survival, or ROSC.

For the important outcome of **physiologic end points**, we identified 3 very-low-quality studies (downgraded for risk of bias, indirectness, and imprecision).[122–124] One crossover study in 17 adults with prolonged resuscitation from nontraumatic cardiac arrest observed improved peak arterial pressure during compression, systole (114 ± 51 mmHg versus 95 ± 42 mmHg) and end-tidal carbon dioxide ($ETCO_2$; 11.0 ± 6.7 mmHg versus 9.6 ± 6.9 mmHg) when compressions were performed in the lower third of the sternum compared with the center of the chest, whereas arterial pressure during compression recoil peak right atrial pressure and coronary perfusion pressure did not differ.[122] A second crossover study in 30 adults observed no difference between $ETCO_2$ values and hand placement.[123] A further crossover study in 10 children observed higher peak systolic pressure and higher mean arterial blood pressure when compressions were performed on the lower third of the sternum compared with the middle of the sternum.[124]

Treatment recommendation

We suggest performing chest compressions on the lower half of the sternum on adults in cardiac arrest (weak recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we place a high value on consistency with current treatment recommendations in the absence of compelling data suggesting the need to change the recommended approach.

Knowledge gaps

- The use of physiologic feedback to optimize hand position in individual patients

Chest compression rate (BLS 343)

Among adults and children who are in cardiac arrest in any setting (P), does any specific rate for external chest compressions (I), compared with a compression rate of about 100/min (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; CPR quality (O)?

Introduction

Chest compression rate can be defined as the actual rate used during each continuous period of chest compressions over 1 min, excluding any pauses. It differs from the number of chest compressions actually delivered in 1 min, which takes into account any interruptions in chest compressions.

In the 2010 CoSTR, we recommended a manual chest compression rate of at least 100/min in adults. We noted the absence of a specific upper limit for compression rate.[105] This review notes the publication of important new observational studies in

humans that suggest the need to limit the upper rate of chest compressions.[125,126]

Consensus on science

No studies addressed the critical outcome of favorable neurologic outcome.

For the critical outcome of **survival to hospital discharge**, we identified very-low-quality evidence from 2 observational studies[125,126] representing 13 469 adult patients. Both studies were downgraded due to risk of bias.[125] They compared chest compression rates of greater than 140/min, 120–139/min, less than 80/min, and 80–99/min with the control rate of 100–119/min. When compared with the control chest compression rate of 100–119/min, there was a

- 4% decrease in survival to hospital discharge with compression rates of greater than 140/min,
- 2% decrease in survival to hospital discharge with compression rates of 120–139/min,
- 1% decrease in survival to hospital discharge with compression rates of less than 80/min,
- 2% decrease in survival to hospital discharge with compression rates of 80–99/min.

The study found a significant relationship between chest compression rate categories and survival without adjustment and when adjusted for covariates, including CPR quality measures such as compression depth and fraction (global test, $P = 0.02$). The study showed chest compression depth declined with increasing chest compression rate. The relationship of reduced compression depth at different compression rates was as follows: for a compression rate of 100–119/min, 35% of compressions had a depth less than 3.8 cm; for a compression rate of 120–139/min, 50% of compressions had a depth less than 3.8 cm; and for a compression rate of 140/min or greater, 70% of the compressions had a depth less than 3.8 cm.

In the second study,[126] there was a 4.1% decrease in survival to hospital discharge with chest compression rates of greater than 140/min and a 1.9% increase in survival to hospital discharge with rates of less than 80/min when compared with the control rate of 80–140/min. The adjusted ORs for survival to hospital discharge were 0.61 ($P = 0.18$) for rates of greater than 140/min and 1.32 ($P = 0.42$) for rates of less than 80/min and, therefore, showed no significant difference in survival to hospital discharge.

For the critical outcome of **ROSC**, we identified very-low-quality evidence from 3 observational studies[125–127] representing 13 566 adult patients. All studies were downgraded due to risk of bias. All studies had different interventions and different control chest compression rates: 100–119/min,[125] 80–140/min,[126] and 80–119/min.[127]

High compression rates. There was a significant decrease in ROSC with chest compression rates of greater than 140/min (OR, 0.72; $P = 0.006$). However, significance was lost when the model was adjusted for covariates (gender, witnessed arrest, bystander CPR, first known EMS rhythm, location).[125] There was a 5% decrease in ROSC with rates of greater than 140/min,[126] and 9% increase in ROSC with rates of greater than 120/min[127] when compared with their respective control chest compression rates.

Low compression rates. With chest compression rates of less than 80/min, there was a 3% increase in ROSC in 1 study[126] and 25% decrease in ROSC in other.[127] The adjusted ORs for ROSC were 1.01 ($P = 0.95$) for rates of greater than 140/min[126] and 1.18 ($P = 0.79$) for rates of less than 80/min.[126] Comparison of mean chest compression rates of 95.5–138.7/min with 40.3–72.0/min showed a +33% increase in ROSC ($P = 0.00925$).[127] Comparison of mean chest compression rates of 87.1–94.8/min with 40.3–72.0/min showed a +33% increase in ROSC ($P = 0.00371$).[127]

For the important outcome of **systolic blood pressure**, we identified very-low-quality evidence from 1 observational study[128] where a mechanical CPR device (Thumper, Michigan Instruments, MI) was used to deliver incremental increases in chest compression rate (from 80 to 140/min) among 18 adult patients. Within subject comparisons showed increasing the compression rate reduced systolic blood pressure (to 74% of baseline at a rate of 140/min, $P < 0.05$) but had no effect on diastolic pressure.

For the important outcome of **$ETCO_2$ levels**, very-low-quality evidence from 2 observational studies[128,129] included 41 adult patients. Both studies were downgraded due to risk of bias. One study showed no difference for compression rates in the range of 60–140/min,[128] while the second showed a small (2 mmHg) increase at higher compression rates.[129]

For the important outcome of **number of chest compressions per minute**, very-low-quality evidence from 1 observational study[126] representing 3098 adult patients was identified. This study was downgraded due to risk of bias. This study compared chest compression rates of greater than 140/min and less than 80/min with the control rate of 80–140/min. The number of chest compressions delivered per minute increased with higher chest compression rates.

Treatment recommendations

We recommend a manual chest compression rate of 100–120/min (strong recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we place a high value on compatibility with the previous guidelines recommendation of a lower compression threshold of at least 100/min to minimize additional training and equipment costs (e.g., reprogramming feedback devices, educational programs). We consider the new evidence that has emerged since 2010 CoSTR as sufficient to suggest that the upper threshold should be limited to no more than 120/min.

Knowledge gaps

- Does optimizing chest compression rate based on a patient's physiologic response improve outcome?

Chest compression depth (BLS 366)

Among adults who are in cardiac arrest in any setting (P), does a different chest compression depth during CPR (I), compared with chest compression depth to 5 cm (2 in.) (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; CPR quality; coronary perfusion pressure; cardiac output; bystander CPR performance (O)?

Introduction

In 2010, we recommended that it is reasonable to compress the sternum at least 5 cm (2 in.) for all adult cardiac arrest victims. We stated that there was insufficient evidence to recommend a specific upper limit for chest compression depth. Important new data have emerged since 2010, which has prompted the revision of our treatment recommendation.

The reader is reminded of our 2010 recommendation that CPR should be performed on a firm surface when possible. Air-filled mattresses should be routinely deflated during CPR. There was insufficient evidence for or against the use of backboards during

CPR. If a backboard is used, rescuers should minimize delay in initiation of chest compressions, minimize interruption in chest compressions, and take care to avoid dislodging catheters and tubes during backboard placement.

Consensus on science

For the critical outcome of **survival with good neurologic outcome** (CPC 1-2), we found low-quality evidence (downgraded for imprecision, upgraded for a dose-response gradient), from 1 observational study[130] suggesting that a compression depth in adults of more than 5 cm (2 inches) is better than all other compression depths during manual CPR. Adjusted OR for each 5 mm increase in mean chest compression depth was 1.33 (1.03–1.71) for favorable functional outcome. Upon review by the evidence evaluation experts during the final iterative ILCOR process (see Part 2), 1 citation was excluded from the final consensus on science.[133]

For the critical outcome of **survival to hospital discharge**, we found very-low-quality evidence (downgraded for imprecision), from 3 observational studies[132,134,135] suggesting that survival may improve with increasing compression depth. The adjusted ORs for survival to hospital discharge per 5 mm increase in mean chest compression depth were 1.09 (95% CI, 0.94 to 1.27),[134] 1.04 (95% CI, 1.00 to 1.08),[135] and 1.30 (95% CI, 1.03 to 1.65).[132] In the largest study (9136 patients) a covariate-adjusted spline analysis showed a maximum survival at a mean depth of 4.0 to 5.5 cm (1.6 to 2.2 inches), with a peak at 4.6 cm (1.8 inches).[135]

For the critical outcome of **ROSC**, we found low-quality evidence (downgraded for imprecision, upgraded for a dose-response gradient) from 4 observational studies[134,135,137,140] suggesting that a compression depth of more than 5 cm (2 inches) in adults is better than all other compression depths during manual CPR. The largest study reported that ROSC increased with each 5 mm increment (adjusted OR 1.06 [95% CI: 1.04 to 1.08, $P < 0.001$]) and that the adjusted OR for ROSC for patients receiving chest compressions with a depth of 3.8 to 5.1 cm (1.5 to 2 inches) compared with more than 5.1 cm (more than 2 inches) was 0.86 (95% CI, 0.75–0.97).[135] Upon review by the evidence evaluation experts during the final iterative ILCOR process (see Part 2), 4 citations were excluded from the final consensus on science.[133,136,138,139]

For the important outcome of **injury**, we found very-low-quality evidence (downgraded for serious risk of bias, imprecision, and very serious indirectness) from 1 observational study suggesting that a compression depth of more than 6 cm (2.4 in.) is associated with an increased rate of injury in adults when compared with compression depths of 5–6 cm (2–2.4 in.) during manual CPR. This study included 170 of 353 patients (183 excluded for incomplete data), and injuries were reported in 63% with compression depth more than 6 cm (more than 2.4 in.) and 31% with compression depth less than 6 cm. Further, injuries were reported in 28%, 27%, and 49% with compression depths less than 5 cm (less than 2 in.), 5–6 cm (2–2.4 in.), and more than 6 cm (more than 2.4 in.), respectively.[139]

Treatment recommendations

We recommend a chest compression depth of approximately 5 cm (2 in.) (strong recommendation, low-quality evidence) while avoiding excessive chest compression depths (greater than 6 cm [greater than 2.4 in.] in an average adult) (weak recommendation, low-quality evidence) during manual CPR.

Values, preferences, and task force insights

In making this recommendation, we place a high value on the consistency with our previous recommendations given the resource implications (e.g., training, reprogramming CPR devices) of making a change, and consistency in data showing harm from compressions that are too shallow. In addition, we note new data from the US and Canadian Resuscitation Outcomes Consortium group reporting a "sweet spot" for compression depth between 4.03 and 5.53 cm (between 1.59 and 2.2 in.; peak, 4.56 cm [1.8 in.]) and harm from excessive compression depths.[133] We used the term *approximately 5 cm* (approximately 2 in.) to reflect these findings plus the known variation in patient shapes and sizes around the world.

We refer the reader to Ped 394 systematic review (see "Part 6: Pediatric Basic Life Support and Pediatric Advanced Life Support") for recommendations in children.

Knowledge gaps

- We need additional studies on the relationship of compression depth and injuries, and how these factors may vary in relation to differences in body/chest size and differences in chest wall compliance and between adults and children. We also need additional studies on the relationship and interaction between chest compression rate and depth.

Chest wall recoil (BLS 367)

Among adults and children who are in cardiac arrest in any setting (P), does maximizing chest wall recoil (I), compared with ignoring chest wall recoil (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; coronary perfusion pressure; cardiac output (O)?

Introduction

Critical to hemodynamically effective CPR is blood returning to the chest between compressions. Venous return is in part influenced by the pressure gradient between extrathoracic and intrathoracic veins. Leaning on the chest wall between compressions, precluding full chest wall recoil, could raise intrathoracic pressure and reduce right heart filling, coronary perfusion pressure, and myocardial blood flow.[140,141] Observational studies indicate that leaning is common during CPR in adults and children.[141,142] This question sought to examine the effect of chest wall leaning during standard manual CPR on outcome.

Consensus on science

For the critical outcomes of ROSC, survival at hospital discharge, and survival with favorable neurologic/functional outcome, we found no evidence to address the question.

For the important outcome of **coronary perfusion pressure**, we found 3 observational studies: 2 in animal models[140,143] and 1 in anesthetized children not in cardiac arrest,[144] which provided very-low-quality evidence, downgraded for serious risk of bias and very serious indirectness. All 3 studies reported a reduced coronary perfusion pressure with incomplete chest recoil. In anesthetized children undergoing mechanical ventilation during cardiac catheterization, Glatz et al. analyzed the effect of leaning by applying a force on the chest corresponding to 10% and 20% of body weight; this resulted in a proportional reduction in coronary perfusion pressure.[144] Yannopoulos et al. and Zuercher et al. reported in swine models of VF that leaning on the chest precluding full chest recoil reduced the coronary perfusion pressure in a dose-dependent manner.[140,143]

For the important outcome of **cardiac output/cardiac index**, we found 2 observational studies (1 in an animal model and 1 in anesthetized children not in cardiac arrest) also representing very-low-quality evidence downgraded for serious risk of bias and very serious indirectness.[140,144] The study in animals reported a proportional reduction in cardiac index when 10% and 20% of the forces applied during compression remained between compressions.[140]

In contrast, Glatz et al. found that leaning forces had no effect on cardiac output.[144]

Treatment recommendation

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).

Values, preferences, and task force insights

In making this recommendation, the task force placed high value on consistency with previous recommendations and in ensuring that a clear recommendation is provided for CPR training and practice. We acknowledge that some studies have reported a leaning threshold below which there are possibly no adverse hemodynamic effects, but the task force anticipates that this would be difficult to measure and teach.

Knowledge gaps

- Impact of full chest recoil in humans and the impact of this recommendation on rescuer performance when factoring in depth, rate, and duty cycle.
- Identification of best options to monitor full chest recoil.

Minimizing pauses in chest compressions (BLS 358)

Among adults and children who are in cardiac arrest in any setting (P), does minimization of pauses in chest compressions for cardiac rhythm analysis or ventilations (I), compared with prolonged pauses in chest compressions for rhythm analysis or ventilations (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; CPR quality; rhythm control (O)?

Introduction

For adults in cardiac arrest without an advanced airway, such as an endotracheal tube, chest compressions are often briefly paused to allow for ventilation. Some CPR guidelines suggest that the duration of pauses for ventilation should not exceed 5 s. However, forceful insufflations to comply with the guideline carry a risk of gastric insufflation, and may not be feasible for mouth-to-mouth ventilation.

Preshock intervals include the time required for assessment of the rhythm, charging, and actually delivering a shock. *Postshock intervals* reflect the time from shock delivery to resumption of chest compression. Achieving short preshock and postshock pauses requires awareness of the importance of minimizing the pause, attention during training, and an excellent interplay among the rescuers working together during a resuscitation attempt. In this systematic review, we examine the possible consequences of interruptions of chest compressions on various critical and important outcomes.

Consensus on science

For the critical outcome of **favorable neurologic outcome**, we found 1 low-quality observational study (downgraded for imprecision)[145] enrolling 199 patients. This study compared survival against a reference ventilation range of 5–6 s and found no difference with longer ranges of time for 2 breaths delivered by lay rescuers, ranging over 10–12 s (adjusted OR, 1.30; 95% CI, 0.29–5.97) and 13 s or greater (adjusted OR, 2.38; 95% CI, 0.46–12.1). We found no studies addressing pauses for rhythm analysis and shock.

For the critical outcome of **survival to hospital discharge**, there were no studies examining duration required to deliver 2 breaths. For perishock pauses, we identified moderate-quality evidence (downgraded for indirectness) from 1 RCT that compared 2 AED algorithms.[146] The study enrolled 845 patients but found no benefit (OR, 0.81; 95% CI, 0.33–2.01) of reducing preshock and postshock pauses. We found moderate-quality evidence from 3 observational studies (upgraded for dose–response gradient)[147–149] including 3327 patients showing a strong relationship with shorter preshock and postshock pauses (less so for postshock pauses) or higher chest compression fraction.

For the critical outcome of **ROSC**, we found no studies addressing the duration required to deliver 2 breaths. For perishock pause, we found 1 very-low-quality observational study[150] (downgraded for risk of bias and imprecision) including 35 patients, indicating benefit from limiting preshock and postshock pauses and 1 very-low-quality study (downgraded for risk of bias)[151] including 2103 patients, suggesting benefit from achieving chest compression fractions (i.e., total CPR time devoted to compressions) greater than 40%.

For the important outcome of **shock success**, we found 1 very-low-quality observational study (downgraded for imprecision)[136] including 60 patients, indicating benefit of shorter preshock pauses: OR of 1.86 (95% CI, 1.10–3.15) for every 5 s.

Treatment recommendations

We suggest that in adult patients receiving CPR with no advanced airway, the interruption of chest compressions for delivery of 2 breaths should be less than 10 s (weak recommendation, low-quality evidence).

We recommend that total preshock and postshock pauses in chest compressions be as short as possible. For manual defibrillation, we suggest that preshock pauses be as short as possible and no more than 10 s (strong recommendation, low-quality evidence).

We suggest during conventional CPR that chest compression fraction (i.e., total CPR time devoted to compressions) should be as high as possible and at least 60% (weak recommendation, low-quality evidence).

Values, preferences, and task force insights

In making these recommendations, we place a high priority on minimizing interruptions for chest compressions. We seek to achieve this overall objective by balancing it with the practicalities of delivering 2 effective breaths between cycles of chest compressions to the patient without an advanced airway.

Knowledge gaps

- Analysis of causes and consequences of pauses for other reasons or without obvious reason.
- Measures to avoid (unnecessary) pauses for rhythm analysis, such as rhythm analysis during chest compressions.

Compression–ventilation ratio (BLS 362)

Among adults and children who are in cardiac arrest in any setting (P), does delivery of CPR with another specific compression–ventilation ratio (I), compared with CPR that uses a 30:2 compression–ventilation ratio (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; hands-off time (O)?

Introduction

For adults in cardiac arrest without an advanced airway, such as an endotracheal tube, chest compressions are often briefly paused to allow for ventilation. In 2005, many guidelines for adults in cardiac arrest were changed from a compression–ventilation

ratio of 15:2 to a ratio of 30:2. This structured review identified 4 observational cohort before–after studies, all conducted in the out-of-hospital setting, that evaluated a bundle of care interventions implemented after the 2005 guidelines and used a 30:2 compression–ventilation ratio, compared with care before the 2005 guidelines that used a 15:2 compression–ventilation ratio.[152–155] No studies were identified that compared a 30:2 compression–ventilation ratio to a compression–ventilation ratio other than 15:2. One observational cohort study,[156] although meeting our inclusion criteria, was excluded due to concerns regarding the study design, analytical technique, and challenges with data reporting and abstraction.

Consensus on science

For the critical outcome of **survival with favorable neurologic outcome at discharge**, we found very-low-quality evidence from 2 observational studies[152,153] that were downgraded for risk of bias and indirectness. Of the 1711 patients included, those who were treated under the 2005 guidelines with a compression–ventilation ratio of 30:2 had slightly higher survival than those patients treated under the 2000 guidelines with a compression–ventilation ratio of 15:2 (8.9% versus 6.5%; RR 1.37 [0.98–1.91]).

For the critical outcome of **survival to hospital discharge**, we identified very-low-quality evidence from 4 observational studies.[152–155] The level of evidence was downgraded for risk of bias and indirectness. Of the 4183 patients included, those who were treated under the 2005 guidelines with a compression–ventilation ratio of 30:2 had slightly higher survival than those patients treated under the 2000 guidelines with a compression-ventilation ratio of 15:2 (11.0% versus 7.0%; RR 1.75 [1.32–2.04]).

For the critical outcome of **survival to 30 days**, we identified very-low-quality evidence from 1 observational study[155] that was downgraded for risk of bias and indirectness. Patients treated under the 2005 guidelines had slightly higher survival than those patients treated under the 2000 guidelines (16.0% versus 8.3%; RR 1.92 [1.28–2.87]).

For the critical outcome of any **ROSC**, we identified very-low-quality evidence from 2 observational studies.[152,153] The studies were downgraded for risk of bias and indirectness. Patients treated under the 2005 guidelines had a ROSC more often than those patients treated under the 2000 guidelines (38.7% versus 30.0%; RR 1.30 [1.14–1.49]).

For the critical outcome of **ROSC at hospital admission**, we identified very-low-quality evidence from 2 observational studies.[153,155] The studies were downgraded for risk of bias and indirectness. Of the 1708 patients included, those treated under the 2005 guidelines had ROSC at hospital admission more often than those patients treated under the 2000 guidelines (34.5% versus 17.1%; RR 2.02 [1.69-2.41]).

For the important outcome of **hands-off time**, we identified very-low-quality evidence from 2 observational studies[153,154] that were downgraded for risk of bias and indirectness. Patients who were treated with the use of the 2005 guidelines had less hands-off time than those patients treated under the 2000 guidelines.

Treatment recommendation

We suggest a compression–ventilation ratio of 30:2 compared with any other compression–ventilation ratio in patients in cardiac arrest (weak recommendation, low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we placed a high priority on consistency with our 2005 and 2010 treatment recommendations and the findings identified in this review, which suggest that the bundle of care (which included changing to a compression to ventilation ratio of 30:2 from 15:2) resulted in more lives being saved. We note that there would likely be substantial resource implications (e.g., reprogramming, retraining) associated with a change in recommendation, and an absence of any data addressing our critical outcomes to suggest our current recommendation should be changed.

Timing of CPR cycles (BLS 346)

Among adults who are in cardiac arrest in any setting (P), does pausing chest compressions at another interval (I), compared with pausing chest compressions every 2 min to assess the cardiac rhythm (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; coronary perfusion pressure; cardiac output (O)?

Introduction

The 2005 and 2010 CoSTR publications recommended that pausing chest compressions to undertake a rhythm check should occur every 2 min. This recommendation is supported by indirect evidence that rescuer fatigue occurs by about 2 min, and a rhythm check is a natural time point, when possible, to change the compressor.

Feedback from the public comment period for this publication supported maintaining consistency with previous recommendations.

Consensus on science

There are currently no studies that directly address the question of optimal CPR intervals and their effect on the identified critical outcomes of survival with favorable neurologic or functional outcome at discharge or survival only at discharge or the important outcomes of ROSC, coronary perfusion pressure, cardiac output.

Treatment recommendation

We suggest pausing chest compressions every 2 min to assess the cardiac rhythm (weak recommendation, low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we placed a high priority on consistency with previous recommendations and the absence of contradictory evidence to prompt a change. We placed value on simplifying resuscitation logistics by coordinating rhythm and pulse checks with standard recommendations for rotating the provider performing chest compressions every 2 min.

Knowledge gaps

- Does the optimal interval for rhythm checks differ for patients with different initial cardiac rhythms?
- Does the duration between collapse and EMS arrival affect the optimal interval to interrupt compressions to check rhythm?
- Do different intervals interfere with the overriding goal of minimizing interruptions in chest compressions?
- What is the relationship between rescuer fatigue, chest compression quality, and the optimal interval to check rhythm?
- What effect does the timing of rhythm checks have on the timing of drug administration?

Check for circulation during BLS (BLS 348)

Among adults and children who are in cardiac arrest in any setting (P), does interruption of CPR to check circulation (I), compared with no interruption of CPR (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days,

and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; chest compression fraction (O)?

Introduction

In the 2015 PICO development process, additional questions were developed to address knowledge gaps identified in 2010. As a result of significant similarities in other BLS PICO questions, very rigid study inclusion criteria were applied. Only comparative human studies assessing the PICO listed outcomes were considered.

Consensus on science

Of the 654 articles found during the search, and a follow-up search performed early in 2015 identifying a potential additional 112 studies, none were found to relate to the specific question.

Treatment recommendation

Outside of the ALS environment where invasive monitoring is available, there is insufficient data around the value of a pulse check while performing CPR. We therefore do not make a treatment recommendation regarding the value of a pulse check.

Values, preferences, and task force insights

Emphasis should remain on minimizing interruptions in chest compressions and avoiding pausing for a pulse check without strong suspicion of ROSC (e.g., clinically or by hemodynamic monitoring).

Knowledge gaps

- Human data around value/accuracy of circulation assessment.

Feedback for CPR quality (BLS 361)

Among adults and children who are in cardiac arrest in any setting (P), does real-time feedback and prompt device regarding the mechanics of CPR quality (e.g., rate and depth of compressions and/or ventilations) (I), compared with no feedback (C), change survival with favorable neurologic outcome; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; bystander CPR rates; time to first compressions; time to first shock; CPR quality (O)?

Introduction

The use of CPR feedback or prompt devices during CPR in clinical practice or CPR training is intended to improve CPR quality as a means to improving ROSC and survival. The forms of CPR feedback or prompt devices include audio and visual components such as voice prompts, metronomes, visual dials, numerical displays, waveforms, verbal prompts, and visual alarms. Visual displays enable the rescuer to see compression-to-compression quality parameters, including compression depth and rate, in real time. All audio prompts may guide CPR rate (e.g., metronome) and may offer verbal prompts to rescuers (e.g., "push harder," "good compressions").

The use of CPR feedback or prompt devices should be considered as part of a broader system of care that should include comprehensive CPR quality improvement initiatives, rather than an isolated intervention. The reader is referred to the relevant sections of the Education, Implementation, and Teams Task Force recommendations, EIT 640: Measuring Quality of Systems, EIT 645: Debriefing of Resuscitation Performance, and EIT 648: CPR Feedback Devices During Training (see "Part 8: Education, Implementation, and Teams").

Consensus on science

This review identified 12 studies, of which 2 studies were randomized studies[131,135] and 10 studies were observational of before–after design.[129,138,141,157–163] The included studies were 9 studies in 3716 adults[129,131,135,138,157,159–162] and 3 studies of 34 pediatric patients.[141,158,163] Four studies included patients with in-hospital cardiac arrest,[141,157,158,163] 7 studies with OHCA[131,135,138,159–162] and 1 study[129] had a mixture of patients from in and out-of-hospital settings.

Feedback devices examined included accelerometer-based devices[131,135,138,141,157,159,161–163] and audiotape of prompts.[129,158,160] Compared with the previous evidence review performed in 2010, this review identified 8 new studies that were included for analysis.[131,135,138,141,159,161–163] The nature of using feedback or prompt devices meant that all studies suffered from performance and detection bias because healthcare professionals were not blinded to intervention (feedback or no feedback).

For the critical outcome of **favorable neurologic outcome**, we identified moderate-quality evidence from 1 cluster-randomized study[131] representing 1586 patients, and very-low-quality evidence from 2 observational studies in adults[159,162] representing 670 patients. All studies were downgraded due to risk of bias. The randomized trial found no difference in the number of patients who achieved favorable neurologic outcome (control 10.1% versus 10.3%, $P = 0.855$). No studies showed a statistically significant difference in favorable neurologic outcome with the use of CPR feedback. Effect of CPR feedback on survival with favorable neurologic outcome ranged from −0.8% to 5.8%.

For the critical outcome of **survival to hospital discharge**, we identified moderate-quality evidence from 1 cluster-randomized study[131] representing 1586 patients, and very-low-quality evidence from 4 observational studies in adults,[138,157,159,162] and 1 observational study in children[163] representing 1192 patients. All studies were downgraded due to risk of bias. The randomized trial found no difference in the number of patients who achieved survival to hospital discharge (control 44.7% versus 44.3%, $P = 0.962$). No studies showed a statistically significant difference in survival to hospital discharge with the use of CPR feedback. The effect of CPR feedback on survival to hospital discharge ranged from −0.9 to 5.2.

For the critical outcome of **ROSC**, we identified moderate-quality evidence from 2 randomized studies[131,135] representing 1886 patients, and very-low-quality evidence from 7 observational studies in adults[135,138,157,159–162] and 1 observational study in children[163] representing 3447 patients. All studies were downgraded due to risk of bias. The randomized trial found no difference in the number of patients who achieved ROSC (control 44.7% versus 44.3%, $P = 0.962$). Only 1 study[162] showed a statistically significant difference in ROSC with the use of feedback; however, in this study, feedback was activated at the discretion of the physician, and no details were provided regarding the decision-making process to activate or not activate feedback. Effect of CPR feedback on ROSC ranged from −4.4% to 17.5%: 1 study demonstrated a 50% increase in ROSC with CPR feedback; however, this small study had only 4 patients in each group.[163]

For the important outcome of **chest compression rate**, we identified moderate-quality evidence from 2 randomized studies[131,135] representing 1474 patients, and very-low-quality evidence from 4 observational studies: 3 in adults[138,157,159] representing 777 patients, and 1 in children[163] representing 8 patients. All studies were downgraded due to risk of bias. The cluster RCT[131] found a significant difference of −4.7/min (95% CI, −6.4 to −3.0/min) when feedback was used, and the prospective randomized trial[137] showed no difference in compression rates with and without feedback. In both randomized trials, compression rates were all close to international recommendations of 100/min. One observational study[157] showed no difference in chest compression rates with and without feedback, and, again, all compression rates were close to

international recommendations of 100/min. The other 2 observational studies[138,159] showed lower compression rates in the group with CPR feedback: 128 to 106/min (difference, −23; 95% CI, −26 to −19)[159] and 121–109/min (difference, −12; 95% CI, −16 to −9).[138] The pediatric study[163] found a median difference of −10/min with feedback, and, again, the chest compression rate in the control group exceeded 120/min. The use of CPR feedback devices may be effective in limiting compression rates that are too fast.

For the important outcome of **chest compression depth**, we identified moderate-quality evidence from 2 randomized studies[131,135] representing 1296 patients, and very-low-quality evidence from 4 observational studies: 3 in adults[138,157,159] representing 777 patients and 1 in children[163] representing 8 patients. All studies were downgraded due to risk of bias. The cluster RCT[131] found a significant +1.6 mm (95% CI, 0.5–2.7) (cluster adjusted) difference in chest compression depth with feedback. However, this is of questionable clinical significance, and the average compression depths in both arms were less than international recommendations of 5 cm (2 in.) in adults (3.96 cm [1.55 in.] and 3.87 cm [1.52 in.]). The prospective randomized trial[135] found no significant difference in compression depth with and without feedback, and all compression depths were close to, but slightly less than, international recommendations of 5 cm (2 in.) in adults. One observational study[157] showed no difference in chest compression depth with and without feedback, and all compression rates were close to, but less than, international recommendations of 5 cm (2 in.) in adult patients (4.4 and 4.3 cm or 1.7 in.). Two observational studies[138,159] showed significantly deeper chest compressions in the groups with CPR feedback: Bobrow et al[159] found a 1.06 cm (0.42 in.) increase with feedback (5.46 versus 4.52 cm, or 2.15 versus 1.78 in.) (mean difference, 0.97 cm; 95% CI, 0.71–1.19 cm), while the findings by Kramer–Johansen[138] were more modest (increase from 3.4 to 3.88 cm, or [from 1.3 to 1.5 inches]) (mean difference, 0.4 cm; 95% CI, 0.2–0.6). The pediatric study[163] found no median difference in compression depth. The use of CPR feedback devices did not seem to make an appreciable difference in chest compression depth.

For the important outcome of **chest compression fraction**, we identified moderate-quality evidence from 1 randomized study[131] and very-low-quality evidence from 3 observational studies in adults[138,157,159] and 1 in children.[163] All studies were downgraded due to risk of bias. The randomized study found a cluster adjusted difference of +1.9% (65.9% versus 64.0%; $P = 0.016$) when CPR prompt devices were used. Although statistically significant, such a small difference has questionable clinical significance. The adult studies found no significant difference between groups, and the sample size of the pediatric study was too small to enable inferential statistical analysis. The use of CPR feedback devices did not seem to make an appreciable difference in chest compression fraction.

For the important outcome of **ventilation rate**, we identified very-low-quality evidence from 3 observational studies in adults[138,157,159] representing 532 patients. All studies were downgraded due to risk of bias. None of the studies showed a significant difference in ventilation rate with and without CPR feedback.

For the important outcome of **$ETCO_2$**, we identified very-low-quality evidence from 2 observational studies in adults[129,159] representing 131 patients. All studies were downgraded due to risk of bias. Kern[129] found that the $ETCO_2$ was significantly higher when CPR feedback was used (+6.3 mmHg with compression rate feedback of 120/min and +4.3 mmHg with compression rate feedback of 80/min). Bobrow[159] found an absolute difference of −2.2 mm Hg with CPR feedback. The clinical significance of these differences is questionable.

For the important outcome of **leaning force** during chest compressions, we identified very-low-quality evidence from 1 observational study in children[141] representing 20 patients. This study was downgraded due to risk of bias. Leaning force was decreased by 0.9 kg with the use of feedback.

Treatment recommendation

We suggest the use of real-time audiovisual feedback and prompt devices during CPR in clinical practice as part of a comprehensive system for care for cardiac arrest (weak recommendation, very-low-quality evidence).

We suggest against the use of real-time audiovisual feedback and prompt devices in isolation (i.e., not part of a comprehensive system of care) (weak recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we place a higher value on development of systems of care with continuous quality improvement than on cost. Resource-poor environments may choose not to adopt this technology in favor of allocating resources to other system developments. Devices that provide real-time CPR feedback also document CPR metrics that may be used to debrief and inform strategies aimed at improving CPR quality. Currently available audiovisual feedback devices provide information on key CPR parameters such as compressions and ventilation; however, the optimal targets and the relationships among different targets have not been fully defined.

Knowledge gaps

- In adults and children sustaining in-hospital or out-of-hospital cardiac arrest, what effect does a chest compression rate of 100–120/min, compared with rates of less than 100/min or greater than 120/min, have on CPR quality improvement initiatives compared with no such initiatives on survival and other clinical and cost-effectiveness outcomes?

EMS chest compression-only versus conventional CPR (BLS 360)

Among adults who are in cardiac arrest outside of a hospital (P), does provision of chest compressions with delayed ventilation by EMS (I), compared with chest compressions with early ventilation by EMS (C), change survival with favorable neurologic outcome; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; time to first compressions; CPR quality (O)?

Introduction

The treatment of a patient with OHCA is extremely complex from several perspectives. Operationally, there is very significant heterogeneity in EMS systems design (e.g., emergency medical responder versus emergency medical technician versus paramedic versus physician based) and resource availability (e.g., number of rescuers, equipment, evidence-based protocols, quality improvement programs). Clinically, there is extreme patient and arrest location variability, with patients located in urban, rural, and remote patient settings and in unpredictable and diverse environments with variable rates of bystander CPR and AED use. Logistically, the initial EMS care of an OHCA victim involves several concurrent goals with complex interactions of scene safety, patient assessment, patient care, communication, extrication, and transport.

This systematic review found no studies that directly addressed the question of EMS compression-only CPR compared with conventional CPR. Four North American observational studies were identified, which adopted a bundled intervention for adult patients, with a presumed cardiac cause of their cardiac arrest.[164–167] EMS response intervals in these settings were generally within 5–6 min.

The bundled interventions were broadly similar and comprised 200 initial chest compressions, a single shock rather than stacked shocks, and immediate resumption of a further 200 chest compressions before rhythm/pulse check. Epinephrine was given early and endotracheal intubation delayed. Basic airway adjuncts were used with either passive oxygen insufflation or bag-mask ventilation (ventilation rate 8/min). The findings from the review provide evidence about the effects of the bundled intervention rather than delayed ventilation in isolation.

Consensus on science

For the critical outcome of **survival to hospital discharge** with favorable neurologic outcome in all OHCAs, we have identified very-low-quality evidence (downgraded for risk of bias and indirectness) from 1 observational trial[166] that enrolled 1019 patients showing no benefit (unadjusted OR, 1.07; 95% CI, 1.41–8.79).

For the critical outcome of **survival with favorable neurologic outcome** in the subset of witnessed arrest/shockable rhythm OHCA, we identified very-low-quality evidence (downgraded for risk of bias and indirectness) from 3 observational studies[164–166] that enrolled 1325 patients showing benefit: OR, 3.6 (95% CI, 1.77–7.35)[164]; OR, 5.24 (95% CI, 2.16–12.75)[165]; and adjusted OR, 2.5 (95% CI, 1.3–4.6).[166]

For the critical outcome of **survival to hospital discharge** in the subgroup of all OHCAs, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from 3 observational studies[167,168] showing benefit: OR, 3.26 (95% CI, 2.46–4.34)[167]; OR, 2.50 (95% CI, 1.75–3.58; cohort)[168]; and OR, 3.05 (95% CI, 1.07–8.66; before–after).[168]

For the critical outcome of **survival to hospital discharge** in the subgroup of witnessed arrest/shockable rhythm cardiac arrest, we identified very-low-quality evidence (downgraded for indirectness and imprecision) in 3 observational studies[164,165,168] that showed benefit: OR, 3.67 (95% CI, 1.98–7.12)[164]; OR, 5.58 (95% CI, 2.36–13.20)[165]; OR, 2.94 (95% CI, 1.82–4.74); and OR, 4.3 (95% CI, 0.98–19.35).[168]

For the critical outcome of **ROSC** in all out of hospital cardiac arrest patients, we identified very-low-quality evidence (downgraded for risk of bias and indirectness) in 1 observational study[166] showing no benefit (OR, 0.85; 95% CI, 0.64–1.11) to EMS provision of chest compressions with delayed ventilation.

Treatment recommendation

We suggest that where EMS systems[2] have adopted bundles of care involving minimally interrupted cardiac resuscitation,[3] the bundle of care is a reasonable alternative to conventional CPR for witnessed shockable out of hospital cardiac arrest (weak recommendation, very-low-quality evidence).

Values, preferences, and task force insights

This recommendation places a relatively high value on (1) the importance of provision of high-quality chest compressions and (2) simplifying resuscitation logistics in the out-of-hospital setting in a defined EMS system with demonstrated clinical benefit, and a relatively low value on the uncertain effectiveness, acceptability, feasibility, and resource use in different EMS systems compared with those in this CoSTR.

We acknowledge the pending results of the important and very large clinical trial NCT01372748 with a primary aim to compare survival at hospital discharge after continuous chest compressions versus conventional CPR with interrupted chest compressions in patients with OHCA.

Knowledge gaps

The following knowledge gaps currently exist:

- The need for higher-quality evidence (e.g., RCT).
- The effect of delayed ventilation versus 30:2 high-quality CPR.
- The duration of maximum delay in positive-pressure ventilation.

Passive ventilation technique (BLS 352)

Among adults and children who are in cardiac arrest in any setting (P), does addition of any passive ventilation technique (e.g., positioning the body, opening the airway, passive oxygen administration) to chest compression-only CPR (I), compared with just chest compression-only CPR (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; bystander initiated CPR; oxygenation (O)?

Introduction

During chest compression-only CPR in the out of hospital setting, some described EMS systems have chosen to provide passive ventilation in the form of an airway maneuver and/or device combined with an oxygen-delivery mask. No studies were found describing this in the lay rescuer setting.

Three studies were identified. Two compared intermittent positive-pressure ventilation via an endotracheal tube with continuous insufflation of oxygen through a modified endotracheal tube.[169,170] The third study compared placement of an oropharyngeal airway and administration of oxygen by nonrebreather mask or by bag-mask ventilation during a bundle of care involving 200 continuous chest compressions and delayed intubation.[166]

Consensus on science

For the critical outcome of **favorable neurologic outcome**, we identified very-low-quality evidence (downgraded due to serious risk of bias and indirectness) from 1 retrospective study, which involved 1019 patients that showed no difference between passive (nonrebreather mask) and active (bag-mask) ventilation[166] (adjusted OR, 1.2; 95% CI, 0.8–1.9).

For the critical outcome of **survival**, we found very-low-quality evidence from a single retrospective study (downgraded for serious indirectness and risk of bias).[166] This study reported no significant difference in survival (RR, 1.1; 95% CI, 0.72–1.54).

For the critical outcome of **ROSC**, we found very-low-quality evidence (downgraded for serious indirectness and risk of bias) from 2 RCTs[169,170] and 1 observational study.[166] None of the studies showed any significant difference: OR, 0.88 (95% CI, 0.6–1.3)[170]; OR, 0.8 (95% CI, 0.7–1.0)[166]; and RR, 1.27 (95% CI, 0.6–2.61).[169]

Treatment recommendation

We suggest against the routine use of passive ventilation techniques during conventional CPR (weak recommendation, very-low-quality evidence).

We suggest that where EMS systems have adopted bundles of care involving continuous chest compressions, the use of passive ventilation techniques may be considered as part of that bundle for patients in OHCA (weak recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we place priority on consistency with our previous recommendations in the absence of

[2] Priority-based dispatch systems, multitiered response, EMS in urban and rural communities.

[3] Up to 3 cycles of passive oxygen insufflation, airway adjunct insertion, and 200 continuous chest compressions with interposed shocks.

compelling evidence for improvement in any of our critical outcomes. We acknowledge that where EMS systems have adopted a bundle of care that includes passive ventilation, it is reasonable to continue in the absence of compelling evidence to the contrary.

Knowledge gaps

- Which elements of the bundled care (compressions, ventilations, delayed defibrillation) are most important?
- What is the optimal method for ensuring a patent airway?
- Is there a critical volume of air movement required to maintain effectiveness?
- How effective is passive insufflation in children?

Harm from CPR to victims not in cardiac arrest (BLS 353)

Among adults and children who are not in cardiac arrest outside of a hospital (P), does provision of chest compressions from lay rescuers (I), compared with no use of chest compressions (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; harm (e.g., rib fracture); complications; major bleeding; risk of complications (e.g., aspiration); survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival to admission (O)?

Introduction

Many lay rescuers are concerned that delivering chest compressions to a person who is not in cardiac arrest could lead to serious complications and, thus, are reluctant to initiate CPR even when a person is actually in cardiac arrest. Studies reporting harm from CPR to persons not in cardiac arrest were reviewed.

Consensus on science

For the important outcome of "**harm**," we identified very-low-quality evidence (downgraded for risk of bias and imprecision) from 4 observational studies enrolling 762 patients who were not in cardiac arrest and received CPR by lay rescuers outside the hospital.[171–174] Three of the studies[171–173] reviewed the medical records to identify harm, and 1 included follow-up telephone interviews.[171] Pooled data from these 3 studies, encompassing 345 patients, found an incidence of bone fracture (ribs and clavicle) of 1.7% (95% CI, 0.4–3.1%), pain in the area of chest compression of 8.7% (95% CI, 5.7–11.7%), and no clinically relevant visceral injury. The fourth study[174] relied on fire department observations at the scene, and there were no reported injuries in 417 patients.

Treatment recommendation

We recommend that laypersons initiate CPR for presumed cardiac arrest without concerns of harm to patients not in cardiac arrest (strong recommendation, very-low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we place a higher value on the survival benefit of CPR initiated by laypersons for patients in cardiac arrest against the low risk of injury in patients not in cardiac arrest.

Knowledge gaps

- More studies are needed with robust methodology to identify harm and provide follow-up after hospital discharge. Many of the conditions prompting initiation of CPR for those not in cardiac arrest are associated with reduced responsiveness and have poor prognosis. Whether chest compressions and rescue breaths could accentuate these conditions independent of physical injury, though unlikely, is not known at the present time.
- The incidence of chest wall bone fractures was substantially lower than the incidence reported after CPR in patients who were in cardiac arrest. This is likely the result of shorter duration of CPR (approximately 6 min) initiated by laypersons but stopped by professional rescuers, and younger patient age in the studies reviewed. However, the possibility of underreporting due to nonsystematic diagnostic studies cannot be excluded, and further research is warranted.
- Could the accuracy of dispatcher-assisted protocol be enhanced to reduce the frequency of CPR performed on patients not in cardiac arrest without compromising the initiation of CPR on patients in cardiac arrest?

Early defibrillation

This section reviews (1) the evidence surrounding the clinical benefit of AEDs in the out-of-hospital setting by laypeople and healthcare providers, and (2) the complex choreography of care needed to ensure high-quality CPR and effective defibrillation. Collectively, we continue to place strong emphasis on the importance of rapid defibrillation as the treatment of choice for VF/pVT in the out-of-hospital and hospitalized settings.

Public-access defibrillation (BLS 347)

Among adults and children who are in cardiac arrest outside of a hospital (P), does implementation of a public-access AED program (I), compared with traditional EMS response (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; bystander CPR rates; bystander use of AED; time to commence CPR (O)?

Introduction

Population (e.g., rates of witnessed arrest) and EMS program (e.g., response intervals) characteristics affect survival and can vary considerably. The concept of early defibrillation is well established in improving outcome from cardiac arrest. This review identified 15 relevant studies (1 RCT and 14 observational studies) spanning the years 2002–2013, with the associated variations in recommended practice of bystander CPR during these periods. The authors recognize that some studies may involve repeat analysis and reporting of the same cardiac arrest population, which limits the ability to provide a summative effect measure in the reported analyses.

Consensus on science

For the critical outcome of **survival to 1 year with favorable neurologic outcome**, we identified very-low-quality evidence (downgraded for risk of bias) from 1 observational trial[175] enrolling 1394 patients showing improved outcomes with public-access defibrillation (unadjusted OR, 3.53; 95% CI, 1.41–8.79).

For the critical outcome of **survival 30 days with favorable neurologic outcome**, we identified very-low-quality evidence (downgraded for inconsistency and indirectness) from 3 observational studies[176–178] enrolling 182 119 patients demonstrating improved survival (range, 31.6–55%) with public-access defibrillation compared with no program (range, 3–37%).

For the critical outcome of **survival to discharge with favorable neurologic outcome**, we identified very-low-quality evidence (downgraded for risk of bias, inconsistency, and imprecision) from 1 randomized trial[179] and 3 observational studies.[175,180,181] The randomized trial enrolled 235 patients and found no difference in favorable neurologic outcomes (CPC, 1–2; RR, 1.73; 95% CI, 0.95–3.19). The observational studies included 4581 patients demonstrating improved survival (range, 4.1–50%) with public-access defibrillation compared with no program (1.4–14.8%), and 1 observational pilot study (20 patients)[182] showing reduced

survival (0% versus 30.7) with public-access defibrillation compared with no program.

For **survival to 30 days**, we identified very-low-quality evidence (downgraded for indirectness) from 3 observational studies[176,178,183] enrolling 14 135 patients demonstrating improved survival (range, 37.2–65.5%) with public-access defibrillation compared with no program (23.3–48.5%). If combined in a formal meta-analysis, a summary effect measure of OR 1.63 (95% CI, 1.41–1.88) would be generated. However, we recognize the limitations of significant heterogeneity in the study populations and the fact that some patient data were reported in more than 1 publication.

For **survival to discharge**, we identified very-low-quality evidence (downgraded for risk of bias, indirectness, and imprecision) from 1 randomized trial[179] and 9 observational studies.[175,180,181,184–189] The randomized trial enrolled 235 participants and observed improved survival (adjusted RR, 2.0; 95% CI, 1.07–3.77). The observational studies enrolled 46 070 patients demonstrating improved survival (range, 4.4–51%) with public-access defibrillation compared with no program (1.4–25.0%) and 1 observation pilot study (20 patients)[182] showing reduced survival (0% versus 30.7%) when public-access defibrillation programs were present.

Treatment recommendation

We recommend the implementation of public-access defibrillation programs for patients with OHCAs (strong recommendation, low-quality evidence).

Values, preferences, and task force insights

In making this recommendation, we considered the societal impact of delayed defibrillation and balanced this against the costs of setting up a comprehensive public-access defibrillation program. We place a higher value on a single randomized trial supported by multiple large-scale, international observational studies. Together, these indicate that the magnitude of change on outcome may vary based on the setting or community within which programs are introduced. Public sites with large population densities may benefit the most from public-access defibrillation programs.

Knowledge gaps

The following knowledge gaps currently exist:

- Community or program characteristics of effective public AED programs.
- Cost-benefit, cost-effectiveness, cost-utility of public AED programs.
- Optimal public AED deployment strategies.
- Effectiveness of public AED with chest compression-only CPR versus 30:2 high-quality CPR.
- Effectiveness of public AED programs with optimal postarrest care.
- Effectiveness of public AED programs with volunteer-enhanced EMS response models and/or digital/social media tools/applications for public AED deployment.

Rhythm check timing (BLS 345)

Among adults and children who are in cardiac arrest in any setting (P), does checking the cardiac rhythm immediately after defibrillation (I), compared with immediate resumption of chest compressions with delayed check of the cardiac rhythm (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; recurrence of VF (O)?

Introduction

The 2010 CoSTR stated that interruptions in chest compressions during CPR must be minimized. Legitimate reasons for the interruption of CPR were highlighted as the needs to ventilate, to assess the rhythm or ROSC, and to defibrillate. This question sought to identify the optimal timing of rhythm checks in relation to attempted defibrillation. Public comments on this question during the consultation process highlighted concerns about drug administration without first confirming whether ROSC had been achieved after shock delivery. This latter concern fell outside the remit of this question but has been highlighted as an area requiring future research.

This review identified 5 observational studies relevant to this question. In each case, the studies evaluated omitting a rhythm check immediately after CPR as part of a bundle of interventions (e.g., elimination of 3 stacked shocks and postshock rhythm and pulse checks). Thus, the evidence presented in this review must be considered as indirect evidence with respect to this narrow question.

Consensus on science

For the critical outcome of **survival with favorable neurologic outcome at discharge**, we identified very-low-quality evidence (downgraded for serious risk of bias, indirectness, and imprecision) from 3 observational studies enrolling 763 OHCAs showing a harmful effect for interrupting chest compressions to check rhythm immediately after shock delivery (RR, 0.62; 95% CI, 0.51–0.75).[165,168,190]

For the critical outcome of **survival hospital discharge**, we identified low-quality evidence from 1 RCT enrolling 845 OHCAs showing no benefit for interrupting chest compressions to check rhythm immediately after shock delivery (RR, 0.80; 95% CI, 0.55–1.15)[146] and very-low-quality evidence (downgraded for serious risk of bias and indirectness) from 3 observational studies enrolling 3094 OHCAs showing a harm effect for checking rhythm immediately after defibrillation (RR, 0.55; 95% CI, 0.45–0.67).[165,168,190] In addition, for the same outcome, we identified very-low-quality evidence from 1 observational study of 528 victims of OHCA showing potential harm for interrupting chest compressions to check rhythm immediately after shock delivery (RR, 0.42; 95% CI, 0.29–0.61).[168]

For the critical outcome of **survival to hospital admission**, we identified low-quality evidence from 1 RCT enrolling 845 victims of OHCA showing no benefit for interrupting chest compressions to check rhythm immediately after shock delivery (RR, 0.99; 95% CI, 0.85–1.15).[146]

For the critical outcome of **ROSC**, we identified very-low-quality evidence (downgraded for serious risk of bias and indirectness) from 2 observational studies enrolling 2969 victims of OHCA showing a harm effect for interrupting chest compressions to check rhythm immediately after shock delivery (RR, 0.69; 95% CI, 0.61–0.78).[168,190]For the important outcome of **recurrence of VF**, we identified low-quality evidence from 1 RCT, enrolling 136 OHCAs showing no benefit for interrupting chest compressions to check rhythm immediately after shock delivery (RR, 1.00; 95% CI, 0.81–1.23).[191.]

Treatment recommendation

We suggest immediate resumption of chest compressions after shock delivery for adults in cardiac arrest in any setting (weak recommendation, very-low-quality evidence).

If there is alternative physiologic evidence of ROSC (e.g., arterial waveform or rapid rise in $ETCO_2$), chest compressions can be paused briefly for rhythm analysis.

Values, preferences, and task force insights

In making this recommendation, we place a higher value on avoiding interruptions in chest compressions for an intervention showing no benefit for critical and important outcomes. Also, this recommendation assumes that shocks are generally effective and that a perfusing rhythm is generally not present immediately after elimination of VF.

Knowledge gaps

- Utility of other monitoring methods (e.g., arterial waveform, $ETCO_2$).
- The timing of rhythm checks during advanced life support interventions, including drug administration.

Analysis of rhythm during chest compression (BLS 373)

Among adults and children who are in cardiac arrest in any setting (P), does analysis of cardiac rhythm during chest compressions (I), compared with standard care (analysis of cardiac rhythm during pauses in chest compressions) (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; time to commence CPR; CPR quality (O)?

Introduction

Motion artifacts effectively preclude the possibility of reliably assessing the heart rhythm during chest compressions. This has 2 undesirable consequences: first, it forces the rescuer to stop chest compressions to assess the rhythm to determine if a shock (or another shock) is required. Second, during chest compressions, possible recurrence of VF cannot be recognized, eliminating the possible beneficial effect of immediate defibrillation in case of refibrillation. Some modern defibrillators contain filtering modalities that allow visual or automated rhythm analysis during chest compressions. This review sought to examine the use of such technology to determine if it leads to better clinically meaningful outcomes in human cardiac arrest.

Consensus on science

There are currently no human studies that address the identified critical outcomes criteria of favorable neurologic outcome, survival, or ROSC or the important outcomes criteria of CPR quality, time to commencing CPR, or time to first shock.

Treatment recommendations

We suggest against the introduction of artifact-filtering algorithms for analysis of electrocardiographic rhythm during CPR unless as part of a research program.

We suggest that where EMS systems have already integrated artifact-filtering algorithms into clinical practice, it is reasonable to continue with their use.

Values, preferences, and task force insights

In making this recommendation, we placed priority on avoiding the costs of introducing a new technology where the effectiveness or harm on patient outcomes remains to be determined. Where such technologies have already been implemented, we place priority on avoiding the likely costs and inconvenience of their withdrawal from practice. We encourage such systems to report on their experiences to build the evidence base regarding the use of these technologies in clinical practice.

Knowledge gaps

- Among adults and children in cardiac arrest, the analysis of cardiac rhythm during chest compressions offers the potential to reduce pauses in chest compressions. The clinical value of this requires evaluation.

2005 and 2010 topics not reviewed in 2015

The following topics were included in 2010 but not in this publication (deferred standardized reviews):

- Etiology of cardiac arrest
- Incidence of cardiac arrest
- Recognition of cardiac arrest
- Facedown victim
- Finding the right hand placement
- Lay rescuer compression-only versus no CPR
- Rescuer fatigue in chest compression-only CPR
- Alternative compression techniques
- Interposed abdominal compressions (IAC) CPR
- Harm to rescuers from CPR
- Opening the airway
- Foreign-body airway obstruction
- Barrier devices
- Oropharyngeal adjuncts
- Tidal volumes and ventilation rates

The reader is referred to the 2010 CoSTR publication for the reviews.[105,192]

The following topics were included in 2005 but not in this publication:

- Devices for airway positioning
- Duty cycle
- CPR in prone position
- Leg-foot chest compressions
- Mouth-to-nose ventilation
- Mouth-to-tracheal stoma ventilation
- Recovery position
- Airway opening
- CPR for drowning victim in water
- Removing drowning victim from water
- Improving EMS response interval

The reader is referred to the 2005 publication for the reviews.[196,197]

Summary

This review comprises the most extensive literature search and evidence evaluation to date on the most important international BLS interventions, diagnostics, and prognostic factors for cardiac arrest victims. It reemphasizes that the critical lifesaving steps of BLS are (1) prevention, (2) immediate recognition and activation of the emergency response system, (3) early high-quality CPR, and (4) rapid defibrillation for shockable rhythms.

Highlights in prevention indicate the rational and judicious deployment of search-and-rescue operations in drowning victims and the importance of education on opioid-associated emergencies. Other 2015 highlights in recognition and activation include the critical role of dispatcher recognition and dispatch-assisted chest compressions, which has been demonstrated in multiple international jurisdictions with consistent improvements in cardiac arrest survival.

Similar to the 2010 ILCOR BLS treatment recommendations, the importance of high quality was reemphasized across all measures of CPR quality: rate, depth, recoil, and minimal chest compression pauses, with a universal understanding that we all should be providing chest compressions to all victims of cardiac arrest. This review continued to focus on the interface of BLS sequencing and ensuring high-quality CPR with other important BLS interventions, such as ventilation and defibrillation. In addition, this consensus statement highlights the importance of EMS systems, which employ bundles of care focusing on providing high-quality chest compressions while extricating the patient from the scene to the next level of care. Highlights in defibrillation indicate the global importance of increasing the number of sites with public-access defibrillation programs.

Whereas the 2010 ILCOR Consensus on Science provided important direction for the "what" in resuscitation (i.e., what to do), the 2015 consensus has begun with the GRADE methodology to provide direction for the quality of resuscitation. We hope that resuscitation councils and other stakeholders will be able to translate this body of knowledge of international consensus statements to build their own effective resuscitation guidelines.

Disclosures

2015 CoSTR Part 3: Adult Basic Life Support and Automated External Defibrillation: Writing Group Disclosures.

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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 $10 000 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 $10 000 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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Appendix A.

CoSTR Part 3: PICO Appendix

Part	Task Force	PICO ID	Short Title	PICO Question	Evidence Reviewers
Part 3	BLS	BLS 343	Chest compression rate	Among adults and children who are in cardiac arrest in any setting (P), does any specific rate for external chest compressions (I), compared with a compression rate of about 100/min (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC;	Julie Considine, Nicolas Mpotos, Swee Lim
Part 3	BLS	BLS 345	Rhythm check timing	Among adults and children who are in cardiac arrest in any setting (P), does checking the cardiac rhythm immediately after defibrillation (I), compared with immediate resumption of chest compressions with delayed check of the cardiac rhythm (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; recurrence of VF (O)?	Giuseppe Ristagno, Husein Lockhat
Part 3	BLS	BLS 346	Timing of CPR cycles	Among adults who are in cardiac arrest in any setting (P), does pausing chest compressions at another interval (I), compared with pausing chest compressions every 2 minutes to assess the cardiac rhythm (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; coronary perfusion pressure; cardiac output (O)?	Joshua Reynolds, Violetta Raffay
Part 3	BLS	BLS 347	Public-Access Defibrillation	Among adults and children who are in cardiac arrest outside of a hospital (P), does implementation of a public-access AED program (I), compared with traditional EMS response (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; bystander CPR rates; bystander use of AED; time to commence CPR (O)?	Andrew Travers, Ian Drennan
Part 3	BLS	BLS 348	Check for circulation during BLS	Among adults and children who are in cardiac arrest in any setting (P), does interruption of CPR to check circulation (I), compared with no interruption of CPR (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; chest compression fraction (O)?	Martin Botha, Andrea Scapigliati
Part 3	BLS	BLS 352	Passive ventilation technique	Among adults and children who are in cardiac arrest in any setting (P), does addition of any passive ventilation technique (e.g., positioning the body, opening the airway, passive oxygen administration) to chest compression–only CPR (I), compared with just chest compression–only CPR (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; bystander initiated CPR; oxygenation (O)?	Emmanuelle Bourdon, Volker Wenzel
Part 3	BLS	BLS 353	Harm From CPR to Victims Not in Cardiac Arrest	Among adults and children who are not in cardiac arrest outside of a hospital (P), does provision of chest compressions from lay rescuers (I), compared with no use of chest compressions (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; harm (e.g., rib fracture); complications; major bleeding; risk of complications (e.g., aspiration); survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival to admission (O)?	Raul Gazmuri, Hermann Brugger
Part 3	BLS	BLS 357	Hand position during compressions	Among adults and children who are receiving chest compressions in any setting (P), does delivery of chest compressions on the lower half of the sternum (I), compared with any other location for chest compressions (C), survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; cardiac output; harm (eg, rib fracture); coronary perfusion pressure (O)?	Ian Drennan, Sung Phil Chung
Part 3	BLS	BLS 358	Minimizing pauses in chest compressions	Among adults and children who are in cardiac arrest in any setting (P), does minimization of pauses in chest compressions for cardiac rhythm analysis or ventilations (I), compared with prolonged pauses in chest compressions for rhythm analysis or ventilations (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; CPR quality; rhythm control (O)?	Rudolph Koster, Tetsuya Sakamoto

Appendix A (*Continued*)

Part	Task Force	PICO ID	Short Title	PICO Question	Evidence Reviewers
Part 3	BLS	BLS 359	Dispatcher instruction in CPR	Among adults and children who are in cardiac arrest outside of a hospital (P), does the ability of a dispatch system to provide CPR instructions (I), compared with a dispatch system where no CPR instructions are ever provided (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; delivery of bystander CPR; time to first shock; time to commence CPR; CPR parameters (O)?	Christian Vaillancourt, Michael Sayre
Part 3	BLS	BLS 360	EMS Chest Compression–Only Versus Conventional CPR	Among adults who are in cardiac arrest outside of a hospital (P), does provision of chest compressions with delayed ventilation by EMS (I), compared with chest compressions with early ventilation by EMS (C), change survival with favorable neurologic outcome; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; time to first compressions; CPR quality (O)?	David Stanton, Andrew Travers
Part 3	BLS	BLS 361	Feedback for CPR quality	Among adults and children who are in cardiac arrest in any setting (P), does real-time feedback and prompt device regarding the mechanics of CPR quality (e.g., rate and depth of compressions and/or ventilations) (I), compared with no feedback (C), change survival with favorable neurologic outcome; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; bystander CPR rates; time to first compressions; time to first shock; CPR quality (O)?	Julie Considine, Joyce Yeung
Part 3	BLS	BLS 362	Compression ventilation ratio	Among adults and children who are in cardiac arrest in any setting (P), does delivery of CPR with another specific compression-ventilation ratio (I), compared with CPR that uses a 30:2 compression-ventilation ratio (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; hands-off time (O)?	Bo Lofgren, Jason Buick
Part 3	BLS	BLS 363	CPR Before Defibrillation	Among adults and children who are in VF or pulseless VT (pVT) in any setting (P), does a prolonged period of chest compressions before defibrillation (I), compared with a short period of chest compressions before defibrillation (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; rhythm control (O)?	Mohamud Daya, Jan-Thorsten Graesner
Part 3	BLS	BLS 366	Chest compression depth	Among adults who are in cardiac arrest in any setting (P), does a different chest compression depth during CPR (I), compared with chest compression depth to 5 cm (2 inches) (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; CPR quality; coronary perfusion pressure; cardiac output; bystander CPR performance (O)?	Ahamed Idris, Koen Monsieurs
Part 3	BLS	BLS 367	Chest wall recoil	Among adults and children who are in cardiac arrest in any setting (P), does maximizing chest wall recoil (I), compared with ignoring chest wall recoil (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; coronary perfusion pressure; cardiac output (O)?	Tyler Vadeboncoeur, Keith Couper
Part 3	BLS	BLS 372	Chest Compression–Only CPR Versus Conventional CPR	Among adults who are in cardiac arrest outside of a hospital (P), does provision of chest compressions (without ventilation) by untrained/trained laypersons (I), compared with chest compressions with ventilation (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; bystander CPR performance; CPR quality (O)?	Andrew Travers, E. Brooke Lerner
Part 3	BLS	BLS 373	Analysis of rhythm during chest compression	Among adults and children who are in cardiac arrest in any setting (P), does analysis of cardiac rhythm during chest compressions (I), compared with standard care (analysis of cardiac rhythm during pauses in chest compressions) (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC; time to first shock; time to commence CPR; CPR quality (O)?	Alfredo Sierra, Kevin Nation
Part 3	BLS	BLS 661	Starting CPR	Among adults and children who are in cardiac arrest in any setting (P), does CPR beginning with compressions first (30:2) (I), compared with CPR beginning with ventilation first (2:30) (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC (O)?	Carl McQueen, Julie Considine
Part 3	BLS	BLS 740	Dispatcher recognition of cardiac arrest	Among adults and children who are in cardiac arrest outside of a hospital (P), does the description of any specific symptoms to the dispatcher (I), compared with the absence of any specific description (C), change the likelihood of cardiac arrest recognition (O)?	Manya Charette, Mike Smyth

Appendix A (*Continued*)

Part	Task Force	PICO ID	Short Title	PICO Question	Evidence Reviewers
Part 3	BLS	BLS 811	Resuscitation care for suspected opioid-associated emergencies	Adults and children with suspected opioid-associated cardiorespiratory arrest in the pre-hospital setting (P), does bystander naloxone administration (intramuscular or intranasal), in addition to conventional CPR (I), compared with conventional CPR only (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC (O)?	Theresa Olasveengen, Aaron Orkin
Part 3	BLS	BLS 856	Drowning Search and Rescue	In adults and children who are submerged in water (P), does any particular factors in search and rescue operations (e.g., duration of submersion, salinity of water, water temperature, age of victim) (I), compared with no factors (C), change Survival with Favorable neurological/functional outcome at discharge, 30 days, 60 days, 180 days AND/OR 1 year, Survival only at discharge, 30 days, 60 days, 180 days AND/OR 1 year; ROSC (O)?	Joost Bierens, Linda Quan
Part 3	BLS	BLS 891	Opioid overdose response education	Adults and children at risk of suspected cardio/respiratory arrest due to opioids in the prehospital setting (P), does opioid overdose response education with or without naloxone distribution (I), compared with no overdose response education or overdose prevention education only (C), change survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival with favorable neurologic/functional outcome at discharge, 30 days, 60 days, 180 days, and/or 1 year; survival only at discharge, 30 days, 60 days, 180 days, and/or 1 year; ROSC (O)?	Aaron Orkin, Theresa Olasveengen

References

1. O'Connor D, Green S, Higgins JPT. Chapter 5: Defining the review questions and developing criteria for including studies. The Cochrane Collaboration. In: Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions. 2011. Version 5.1.0. http://handbook.cochrane.org/ [accessed 06.05.15].
2. 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.
3. Institute of Medicine. Standards for systematic reviews; 2011. http://www.iom.edu/Reports/2011/Finding-What-Works-in-Health-Care-Standards-for-Systematic-Reviews/Standards.aspx [accessed 06.05.15].
4. Schünemann H, Brożek J, Guyatt G, Oxman A. GRADE Handbook; 2013. http://www.guidelinedevelopment.org/handbook/ [accessed 06.05.15].
5. Higgins JPT, Altman DG, Sterne JAC. Chapter 8.5 The cochrane collaboration's tool for assessing risk of bias. In: Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions. 2011. Version 5.1.0. The Cochrane Collaboration. http://handbook.cochrane.org/ [accessed 06.05.15].
6. Whiting PF, Rutjes AW, Westwood ME, Mallett S, Deeks JJ, Reitsma JB, et al. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. Ann Intern Med 2011;155:529–36.
7. Schünemann H, Brożek J, Guyatt G, Oxman A. 5.2.1 Study limitations (risk of bias). In: GRADE Handbook; 2013. http://www.guidelinedevelopment.org/handbook/ - h.m9385o5z3li7 [accessed 06.05.15].
8. Evidence Prime Inc. GRADEpro Guideline Development Tool; 2015. http://www.guidelinedevelopment.org/ [accessed 06.05.15].
9. Schünemann H, Brożek J, Guyatt G, Oxman A. 5. Quality of evidence. In: GRADE Handbook; 2013. http://www.guidelinedevelopment.org/handbook/ - h.9rdbelsnu4iy [accessed 06.05.15].
10. Schünemann H, Brożek J, Guyatt G, Oxman A. 5.1 Factors determining the quality of evidence. In: GRADE handbook; 2013. http://www.guidelinedevelopment.org/handbook/ - h.9rdbelsnu4iy [accessed 06.05.15].
11. Berdowski J, Beekhuis F, Zwinderman AH, Tijssen JG, Koster RW. Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call. Circulation 2009;119:2096–102.
12. Weiser C, van Tulder R, Stöckl M, Schober A, Herkner H, Chwojka CC, et al. Dispatchers impression plus Medical Priority Dispatch System reduced dispatch centre times in cases of out of hospital cardiac arrest. Pre-alert – a prospective, cluster randomized trial. Resuscitation 2013;84:883–8.
13. Bohm K, Rosenqvist M, Hollenberg J, Biber B, Engerström L, Svensson L. Dispatcher-assisted telephone-guided cardiopulmonary resuscitation: an underused lifesaving system. Eur J Emerg Med 2007;14:256–9.
14. Roppolo LP, Westfall A, Pepe PE, Nobel LL, Cowan J, Kay JJ, et al. Dispatcher assessments for agonal breathing improve detection of cardiac arrest. Resuscitation 2009;80:769–72.
15. Tanaka Y, Taniguchi J, Wato Y, Yoshida Y, Inaba H. The continuous quality improvement project for telephone-assisted instruction of cardiopulmonary resuscitation increased the incidence of bystander CPR and improved the outcomes of out-of-hospital cardiac arrests. Resuscitation 2012;83:1235–41.
16. Heward A, Damiani M, Hartley-Sharpe C. Does the use of the Advanced Medical Priority Dispatch System affect cardiac arrest detection? Emerg Med J 2004;21:115–8.
17. Eisenberg MS, Hallstrom AP, Carter WB, Cummins RO, Bergner L, Pierce J. Emergency CPR instruction via telephone. Am J Public Health 1985;75:47–50.
18. Vaillancourt C, Verma A, Trickett J, Crete D, Beaudoin T, Nesbitt L, et al. Evaluating the effectiveness of dispatch-assisted cardiopulmonary resuscitation instructions. Acad Emerg Med 2007;14:877–83.
19. Clawson J, Olola C, Scott G, Heward A, Patterson B. Effect of a Medical Priority Dispatch System key question addition in the seizure/convulsion/fitting protocol to improve recognition of ineffective (agonal) breathing. Resuscitation 2008;79:257–64.
20. Stipulante S, Tubes R, El Fassi M, Donneau AF, Van Troyen B, Hartstein G, et al. Implementation of the ALERT algorithm, a new dispatcher-assisted telephone cardiopulmonary resuscitation protocol, in non-Advanced Medical Priority Dispatch System (AMPDS) Emergency Medical Services centres. Resuscitation 2014;85:177–81.
21. Cairns KJ, Hamilton AJ, Marshall AH, Moore MJ, Adgey AA, Kee F. The obstacles to maximising the impact of public access defibrillation: an assessment of the dispatch mechanism for out-of-hospital cardiac arrest. Heart 2008;94:349–53.
22. Bång A, Herlitz J, Martinell S. Interaction between emergency medical dispatcher and caller in suspected out-of-hospital cardiac arrest calls with focus on agonal breathing. A review of 100 tape recordings of true cardiac arrest cases. Resuscitation 2003;56:25–34.
23. Dami F, Fuchs V, Praz L, Vader JP. Introducing systematic dispatcher-assisted cardiopulmonary resuscitation (telephone-CPR) in a non-Advanced Medical Priority Dispatch System (AMPDS): implementation process and costs. Resuscitation 2010;81:848–52.
24. Hallstrom AP, Cobb LA, Johnson E, Copass MK. Dispatcher assisted CPR: implementation and potential benefit. A 12-year study. Resuscitation 2003;57:123–9.
25. Nurmi J, Pettilä V, Biber B, Kuisma M, Komulainen R, Castrén M. Effect of protocol compliance to cardiac arrest identification by emergency medical dispatchers. Resuscitation 2006;70:463–9.
26. Castrén M, Kuisma M, Serlachius J, Skrifvars M. Do health care professionals report sudden cardiac arrest better than laymen? Resuscitation 2001;51:265–8.
27. Bång A, Biber B, Isaksson L, Lindqvist J, Herlitz J. Evaluation of dispatcher-assisted cardiopulmonary resuscitation. Eur J Emerg Med 1999;6:175–83.
28. Clark JJ, Culley L, Eisenberg M, Henwood DK. Accuracy of determining cardiac arrest by emergency medical dispatchers. Ann Emerg Med 1994;23:1022–6.
29. Deakin CD, Evans S, King P. Evaluation of telephone-cardiopulmonary resuscitation advice for paediatric cardiac arrest. Resuscitation 2010;81:853–6.
30. Flynn J, Archer F, Morgans A. Sensitivity and specificity of the medical priority dispatch system in detecting cardiac arrest emergency calls in Melbourne. Prehosp Disaster Med 2006;21:72–6.
31. Garza AG, Gratton MC, Chen JJ, Carlson B. The accuracy of predicting cardiac arrest by emergency medical services dispatchers: the calling party effect. Acad Emerg Med 2003;10:955–60.
32. Ma MH, Lu TC, Ng JC, Lin CH, Chiang WC, Ko PC, et al. Evaluation of emergency medical dispatch in out-of-hospital cardiac arrest in Taipei. Resuscitation 2007;73:236–45.
33. Lewis M, Stubbs BA, Eisenberg MS. Dispatcher-assisted cardiopulmonary resuscitation: time to identify cardiac arrest and deliver chest compression instructions. Circulation 2013;128:1522–30.
34. Kuisma M, Boyd J, Väyrynen T, Repo J, Nousila-Wiik M, Holmström P. Emergency call processing and survival from out-of-hospital ventricular fibrillation. Resuscitation 2005;67:89–93.
35. Hauff SR, Rea TD, Culley LL, Kerry F, Becker L, Eisenberg MS. Factors impeding dispatcher-assisted telephone cardiopulmonary resuscitation. Ann Emerg Med 2003;42:731–7.

36. Clawson J, Barron T, Scott G, Siriwardena AN, Patterson B, Olola C. Medical Priority Dispatch System breathing problems protocol key question combinations are associated with patient acuity. Prehosp Disaster Med 2012;27:375–80.
37. Bohm K, Stålhandske B, Rosenqvist M, Ulfvarson J, Hollenberg J, Svensson L. Tuition of emergency medical dispatchers in the recognition of agonal respiration increases the use of telephone assisted CPR. Resuscitation 2009;80:1025–8.
38. Hüpfl M, Selig HF, Nagele P. Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. Lancet 2010;376:1552–7.
39. Hallstrom AP. Dispatcher-assisted "phone" cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. Crit Care Med 2000;28:N190–2.
40. Rea TD, Fahrenbruch C, Culley L, Donohoe RT, Hambly C, Innes J, et al. CPR with chest compression alone or with rescue breathing. N Engl J Med 2010;363:423–33.
41. Svensson L, Bohm K, Castrèn M, Pettersson H, Engerström L, Herlitz J, et al. Compression-only CPR or standard CPR in out-of-hospital cardiac arrest. N Engl J Med 2010;363:434–42.
42. Bray JE, Deasy C, Walsh J, Bacon A, Currell A, Smith K. Changing EMS dispatcher CPR instructions to 400 compressions before mouth-to-mouth improved bystander CPR rates. Resuscitation 2011;82:1393–8.
43. Culley LL, Clark JJ, Eisenberg MS, Larsen MP. Dispatcher-assisted telephone CPR: common delays and time standards for delivery. Ann Emerg Med 1991;20:362–6.
44. Rea TD, Eisenberg MS, Culley LL, Becker L. Dispatcher-assisted cardiopulmonary resuscitation and survival in cardiac arrest. Circulation 2001;104:2513–6.
45. Akahane M, Ogawa T, Tanabe S, Koike S, Horiguchi H, Yasunaga H, et al. Impact of telephone dispatcher assistance on the outcomes of pediatric out-of-hospital cardiac arrest. Crit Care Med 2012;40:1410–6.
46. Goto Y, Maeda T, Goto Y. Impact of dispatcher-assisted bystander cardiopulmonary resuscitation on neurological outcomes in children with out-of-hospital cardiac arrests: a prospective, nationwide, population-based cohort study. J Am Heart Assoc 2014;3:e000499.
47. Maxwell S, Bigg D, Stanczykiewicz K, Carlberg-Racich S. Prescribing naloxone to actively injecting heroin users: a program to reduce heroin overdose deaths. J Addict Dis 2006;25:89–96.
48. Walley AY, Xuan Z, Hackman HH, Quinn E, Doe-Simkins M, Sorensen-Alawad A, et al. Opioid overdose rates and implementation of overdose education and nasal naloxone distribution in Massachusetts: interrupted time series analysis. BMJ 2013;346:f174.
49. Walley AY, Doe-Simkins M, Quinn E, Pierce C, Xuan Z, Ozonoff A. Opioid overdose prevention with intranasal naloxone among people who take methadone. J Subst Abuse Treat 2013;44:241–7.
50. Albert S, Brason 2nd FW, Sanford CK, Dasgupta N, Graham J, et al. Project Lazarus: community-based overdose prevention in rural North Carolina. Pain Med 2011;12:S77–85.
51. Quan L, Mack CD, Schiff MA. Association of water temperature and submersion duration and drowning outcome. Resuscitation 2014;85:790–4.
52. Kieboom JK, Verkade HJ, Burgerhof JG, Bierens JJ, Rheenen PF, Kneyber MC, et al. Outcome after resuscitation beyond 30 minutes in drowned children with cardiac arrest and hypothermia: Dutch nationwide retrospective cohort study. BMJ 2015;350:h418.
53. Frates Jr RC. Analysis of predictive factors in the assessment of warm-water near-drowning in children. Am J Dis Child 1981;135:1006–8.
54. Nagel FO, Kibel SM, Beatty DW. Childhood near-drowning–factors associated with poor outcome. S Afr Med J 1990;78:422–5.
55. Quan L, Wentz KR, Gore EJ, Copass MK. Outcome and predictors of outcome in pediatric submersion victims receiving prehospital care in King County, Washington. Pediatrics 1990;86:586–93.
56. Niu YW, Cherng WS, Lin MT, Tsao LY. An analysis of prognostic factors for submersion accidents in children. Zhonghua Min Guo Xiao Er Ke Yi Xue Hui Za Zhi 1992;33:81–8.
57. Mizuta R, Fujita H, Osamura T, Kidowaki T, Kiyosawa N. Childhood drownings and near-drownings in Japan. Acta Paediatr Jpn 1993;35:186–92.
58. Kyriacou DN, Arcinue EL, Peek C, Kraus JF. Effect of immediate resuscitation on children with submersion injury. Pediatrics 1994;94:137–42.
59. Al-Mofadda SM, Nassar A, Al-Turki A, Al-Sallounm AA. Pediatric near drowning: the experience of King Khalid University Hospital. Ann Saudi Med 2001;21:300–3.
60. Nitta M, Kitamura T, Iwami T, Nadkarni VM, Berg RA, Topjian AA, et al. Out-of-hospital cardiac arrest due to drowning among children and adults from the Utstein Osaka Project. Resuscitation 2013;84:1568–73.
61. Blasco Alonso J, Moreno Pérez D, Milano Manso G, Calvo Macías C, Jurado Ortiz A. Drowning in pediatric patients. An Pediatr (Barc) 2005;62:20–4.
62. Anderson KC, Roy T, Danzl DF. Submersion incidents: a review of 39 cases and development of the submersion outcome score. J Wilderness Med 1991;2:27–36.
63. Orlowski JP. Prognostic factors in pediatric cases of drowning and near-drowning. JACEP 1979;8:176–9.
64. Mosayebi Z, Movahedian AH, Mousavi GA. Drowning in children in Iran: outcomes and prognostic factors. Med J Malaysia 2011;66:187–90.
65. Claesson A, Lindqvist J, Ortenwall P, Herlitz J. Characteristics of lifesaving from drowning as reported by the Swedish Fire and Rescue Services 1996–2010. Resuscitation 2012;83:1072–7.
66. Dyson K, Morgans A, Bray J, Matthews B, Smith K. Drowning related out-of-hospital cardiac arrests: characteristics and outcomes. Resuscitation 2013;84:1114–8.
67. Claesson A, Lindqvist J, Herlitz J. Cardiac arrest due to drowning – changes over time and factors of importance for survival. Resuscitation 2014;85:644–8.
68. Vähätalo R, Lunetta P, Olkkola KT, Suominen PK. Drowning in children: Utstein style reporting and outcome. Acta Anaesthesiol Scand 2014;58:604–10.
69. Claesson A, Svensson L, Silfverstolpe J, Herlitz J. Characteristics and outcome among patients suffering out-of-hospital cardiac arrest due to drowning. Resuscitation 2008;76:381–7.
70. Forler J, Carsin A, Arlaud K, Bosdure E, Viard L, Paut O, et al. Respiratory complications of accidental drownings in children. Arch Pediatr 2010;17:14–8.
71. Bierens JJ, van der Velde EA, van Berkel M, van Zanten JJ. Submersion in The Netherlands: prognostic indicators and results of resuscitation. Ann Emerg Med 1990;19:1390–5.
72. Kruus S, Bergström L, Suutarinen T, Hyvönen R. The prognosis of near-drowned children. Acta Paediatr Scand 1979;68:315–22.
73. Graf WD, Cummings P, Quan L, Brutocao D. Predicting outcome in pediatric submersion victims. Ann Emerg Med 1995;26:312–9.
74. Torres SF, Rodríguez M, Iolster T, Siaba Serrate A, Cruz Iturrieta C, Martínez del Valle E, et al. Near drowning in a pediatric population: epidemiology and prognosis. Arch Argent Pediatr 2009;107:234–40.
75. Kaukinen L. Clinical course and prognostic signs in near-drowned patients. Ann Chir Gynaecol 1984;73:34–9.
76. Veenhuizen L, Haasnoot K, van Vught AJ, Bierens JJ, Thunnissen BT, Gemke RJ. Submersion in children; the role of hypothermia and development of adult respiratory distress syndrome. Ned Tijdschr Geneeskd 1994;138:906–10.
77. Quan L, Kinder D. Pediatric submersions: prehospital predictors of outcome. Pediatrics 1992;90:909–13.
78. Suominen PK, Korpela RE, Silfvast TG, Olkkola KT. Does water temperature affect outcome of nearly drowned children. Resuscitation 1997;35:111–5.
79. Panzino F, Quintillá JM, Luaces C, Pou J. Unintentional drowning by immersion. Epidemiological profile of victims attended in 21 Spanish emergency departments. An Pediatr (Barc) 2013;78:178–84.
80. Szpilman D, Soares M. In-water resuscitation – is it worthwhile? Resuscitation 2004;63:25–31.
81. Szpilman D. Near-drowning and drowning classification: a proposal to stratify mortality based on the analysis of 1,831 cases. Chest 1997;112:660–5.
82. Bierens J. Utstein Drowning Meeting. In: Presented at: 2013 World Congress on Drowning Prevention. 2013. http://www.wcdp2013.org/home. [accessed 28.08.15].
83. Tipton MJ, Golden FS. A proposed decision-making guide for the search, rescue and resuscitation of submersion (head under) victims based on expert opinion. Resuscitation 2011;82:819–24.
84. Wanscher M, Agersnap L, Ravn J, Yndgaard S, Nielsen JF, Danielsen ER, et al. Outcome of accidental hypothermia with or without circulatory arrest: experience from the Danish Præstø Fjord boating accident. Resuscitation 2012;83:1078–84.
85. Marsch S, Tschan F, Semmer NK, Zobrist R, Hunziker PR, Hunziker S. ABC versus CAB for cardiopulmonary resuscitation: a prospective, randomized simulator-based trial. Swiss Med Wkly 2013;143:w13856.
86. Lubrano R, Cecchetti C, Bellelli E, Gentile I, Loayza Levano H, Orsini F, et al. Comparison of times of intervention during pediatric CPR maneuvers using ABC and CAB sequences: a randomized trial. Resuscitation 2012;83:1473–7.
87. Kobayashi M, Fujiwara A, Morita H, Nishimoto Y, Mishima T, Nitta M, et al. A manikin-based observational study on cardiopulmonary resuscitation skills at the Osaka Senri medical rally. Resuscitation 2008;78:333–9.
88. Sekiguchi H, Kondo Y, Kukita I. Verification of changes in the time taken to initiate chest compressions according to modified basic life support guidelines. Am J Emerg Med 2013;31:1248–50.
89. American Heart Association in collaboration with International Liaison Committee on Resuscitation. Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care: International Consensus on Science. Part 3: Adult Basic Life Support. Circulation 2000;102:I22–59.
90. Sasson C, Rogers MA, Dahl J, Kellermann AL. Predictors of survival from out-of-hospital cardiac arrest: a systematic review and meta-analysis. Circ Cardiovasc Qual Outcomes 2010;3:63–81.
91. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A, et al. Bystander-initiated rescue breathing for out-of-hospital cardiac arrests of non-cardiac origin. Circulation 2010;122:293–9.
92. Iwami T, Kawamura T, Hiraide A, Berg RA, Hayashi Y, Nishiuchi T, et al. Effectiveness of bystander-initiated cardiac-only resuscitation for patients with out-of-hospital cardiac arrest. Circulation 2007;116:2900–7.
93. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Berg RA, et al. Time-dependent effectiveness of chest compression-only and conventional cardiopulmonary resuscitation for out-of-hospital cardiac arrest of cardiac origin. Resuscitation 2011;82:3–9.
94. Ong ME, Ng FS, Anushia P, Tham LP, Leong BS, Ong VY, et al. Comparison of chest compression only and standard cardiopulmonary resuscitation for out-of-hospital cardiac arrest in Singapore. Resuscitation 2008;78:119–26.
95. SOS-KANTO Study Group. Cardiopulmonary resuscitation by bystanders with chest compression only (SOS-KANTO): an observational study. Lancet 2007;369:920–6.
96. Bobrow BJ, Spaite DW, Berg RA, Stolz U, Sanders AB, Kern KB, et al. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. JAMA 2010;304:1447–54.

97. Olasveengen TM, Wik L, Steen PA. Standard basic life support vs. continuous chest compressions only in out-of-hospital cardiac arrest. Acta Anaesthesiol Scand 2008;52:914–9.
98. Panchal AR, Bobrow BJ, Spaite DW, Berg RA, Stolz U, Vadeboncoeur TF, et al. Chest compression-only cardiopulmonary resuscitation performed by lay rescuers for adult out-of-hospital cardiac arrest due to non-cardiac aetiologies. Resuscitation 2013;84:435–9.
99. Bohm K, Rosenqvist M, Herlitz J, Hollenberg J, Svensson L. Survival is similar after standard treatment and chest compression only in out-of-hospital bystander cardiopulmonary resuscitation. Circulation 2007;116:2908–12.
100. Holmberg M, Holmberg S, Herlitz J, Swedish Cardiac Arrest Registry. Factors modifying the effect of bystander cardiopulmonary resuscitation on survival in out-of-hospital cardiac arrest patients in Sweden. Eur Heart J 2001;22:511–9.
101. Bossaert L, Van Hoeyweghen R. Evaluation of cardiopulmonary resuscitation (CPR) techniques. The Cerebral Resuscitation Study Group. Resuscitation 1989;17:S99–109, discussion S199.
102. Hallstrom A, Cobb L, Johnson E, Copass M. Cardiopulmonary resuscitation by chest compression alone or with mouth-to-mouth ventilation. N Engl J Med 2000;342:1546–53.
103. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. JAMA 1995;274:1922–5.
104. Mohler MJ, Wendel CS, Mosier J, Itty A, Fain M, Clark L, et al. Cardiocerebral resuscitation improves out-of-hospital survival in older adults. J Am Geriatr Soc 2011;59:822–6.
105. Koster RW, Sayre MR, Botha M, Cave DM, Cudnik MT, Handley AJ, et al. Part 5: Adult basic life support: 2010 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Resuscitation 2010;81:e48–70.
106. Sayre MR, Koster RW, Botha M, Cave DM, Cudnik MT, Handley AJ, et al. Part 5: Adult basic life support: 2010 International consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations. Circulation 2010;122:S298–324.
107. Baker PW, Conway J, Cotton C, Ashby DT, Smyth J, Woodman RJ, et al. Defibrillation or cardiopulmonary resuscitation first for patients with out-of-hospital cardiac arrests found by paramedics to be in ventricular fibrillation? A randomised control trial. Resuscitation 2008;79:424–31.
108. Jacobs IG, Finn JC, Oxer HF, Jelinek GA. CPR before defibrillation in out-of-hospital cardiac arrest: a randomized trial. Emerg Med Australas 2005;17:39–45.
109. Ma MH, Chiang WC, Ko PC, Yang CW, Wang HC, Chen SY, et al. A randomized trial of compression first or analyze first strategies in patients with out-of-hospital cardiac arrest: results from an Asian community. Resuscitation 2012;83:806–12.
110. Stiell IG, Nichol G, Leroux BG, Rea TD, Ornato JP, Powell J, et al. Early versus later rhythm analysis in patients with out-of-hospital cardiac arrest. N Engl J Med 2011;365:787–97.
111. Wik L, Hansen TB, Fylling F, Steen T, Vaagenes P, Auestad BH, et al. Delaying defibrillation to give basic cardiopulmonary resuscitation to patients with out-of-hospital ventricular fibrillation: a randomized trial. JAMA 2003;289:1389–95.
112. Bradley SM, Gabriel EE, Aufderheide TP, Barnes R, Christenson J, Davis DP, et al. Survival increases with CPR by Emergency Medical Services before defibrillation of out-of-hospital ventricular fibrillation or ventricular tachycardia: observations from the Resuscitation Outcomes Consortium. Resuscitation 2010;81:155–62.
113. Cobb LA, Fahrenbruch CE, Walsh TR, Copass MK, Olsufka M, Breskin M, et al. Influence of cardiopulmonary resuscitation prior to defibrillation in patients with out-of-hospital ventricular fibrillation. JAMA 1999;281:1182–8.
114. Hayakawa M, Gando S, Okamoto H, Asai Y, Uegaki S, Makise H. Shortening of cardiopulmonary resuscitation time before the defibrillation worsens the outcome in out-of-hospital VF patients. Am J Emerg Med 2009;27:470–4.
115. Koike S, Tanabe S, Ogawa T, Akahane M, Yasunaga H, Horiguchi H, et al. Immediate defibrillation or defibrillation after cardiopulmonary resuscitation. Prehosp Emerg Care 2011;15:393–400.
116. Huang Y, He Q, Yang LJ, Liu GJ, Jones A. Cardiopulmonary resuscitation (CPR) plus delayed defibrillation versus immediate defibrillation for out-of-hospital cardiac arrest. Cochrane Database Syst Rev 2014;9:CD009803.
117. Meier P, Baker P, Jost D, Jacobs I, Henzi B, Knapp G, et al. Chest compressions before defibrillation for out-of-hospital cardiac arrest: a meta-analysis of randomized controlled clinical trials. BMC Med 2010;8:52.
118. Simpson PM, Goodger MS, Bendall JC. Delayed versus immediate defibrillation for out-of-hospital cardiac arrest due to ventricular fibrillation: a systematic review and meta-analysis of randomised controlled trials. Resuscitation 2010;81:925–31.
119. Rea T, Prince D, Morrison L, Callaway C, Aufderheide T, Daya M, et al. Association between survival and early versus later rhythm analysis in out-of-hospital cardiac arrest: do agency-level factors influence outcomes? Ann Emerg Med 2014;64:1–8.
120. Chamberlain D, Smith A, Colquhoun M, Handley AJ, Kern KB, Woollard M. Randomised controlled trials of staged teaching for basic life support: 2 Comparison of CPR performance and skill retention using either staged instruction or conventional training. Resuscitation 2001;50:27–37.
121. Handley AJ. Teaching hand placement for chest compression – a simpler technique. Resuscitation 2002;53:29–36.
122. Cha KC, Kim HJ, Shin HJ, Kim H, Lee KH, Hwang SO. Hemodynamic effect of external chest compressions at the lower end of the sternum in cardiac arrest patients. J Emerg Med 2013;44:691–7.
123. Qvigstad E, Kramer-Johansen J, Tømte Ø, Skålhegg T, Sørensen Ø, Sunde K, et al. Clinical pilot study of different hand positions during manual chest compressions monitored with capnography. Resuscitation 2013;84:1203–7.
124. Orlowski JP. Optimum position for external cardiac compression in infants and young children. Ann Emerg Med 1986;15:667–73.
125. Idris AH, Guffey D, Pepe PE, Brown SP, Brooks SC, Callaway CW, et al. Chest compression rates and survival following out-of-hospital cardiac arrest. Crit Care Med 2015;43:840–8.
126. Idris AH, Guffey D, Aufderheide TP, Brown S, Morrison LJ, Nichols P, et al. Relationship between chest compression rates and outcomes from cardiac arrest. Circulation 2012;125:3004–12.
127. Abella BS, Sandbo N, Vassilatos P, Alvarado JP, O'Hearn N, Wigder HN, et al. Chest compression rates during cardiopulmonary resuscitation are suboptimal: a prospective study during in-hospital cardiac arrest. Circulation 2005;111:428–34.
128. Ornato JP, Gonzalez ER, Garnett AR, Levine RL, McClung BK. Effect of cardiopulmonary resuscitation compression rate on end-tidal carbon dioxide concentration and arterial pressure in man. Crit Care Med 1988;16:241–5.
129. Kern KB, Sanders AB, Raife J, Milander MM, Otto CW, Ewy GA. A study of chest compression rates during cardiopulmonary resuscitation in humans. The importance of rate-directed chest compressions. Arch Intern Med 1992;152:145–9.
130. Vadeboncoeur T, Stolz U, Panchal A, Silver A, Venuti M, Tobin J, et al. Chest compression depth and survival in out-of-hospital cardiac arrest. Resuscitation 2014;85:182–8.
131. Hostler D, Everson-Stewart S, Rea TD, Stiell IG, Callaway CW, Kudenchuk PJ, et al. Effect of real-time feedback during cardiopulmonary resuscitation outside hospital: prospective, cluster-randomised trial. BMJ 2011;342:d512.
132. Stiell IG, Brown SP, Christenson J, Cheskes S, Nichol G, Powell J, et al. What is the role of chest compression depth during out-of-hospital cardiac arrest resuscitation? Crit Care Med 2012;40:1192–8.
133. Stiell IG, Brown SP, Nichol G, Cheskes S, Vaillancourt C, Callaway CW, et al. What is the optimal chest compression depth during out-of-hospital cardiac arrest resuscitation of adult patients? Circulation 2014;130:1962–70.
134. Babbs CF, Kemeny AE, Quan W, Freeman G. A new paradigm for human resuscitation research using intelligent devices. Resuscitation 2008;77:306–15.
135. Bohn A, Weber TP, Wecker S, Harding U, Osada N, Van Aken H, et al. The addition of voice prompts to audiovisual feedback and debriefing does not modify CPR quality or outcomes in out of hospital cardiac arrest – a prospective, randomized trial. Resuscitation 2011;82:257–62.
136. Edelson DP, Abella BS, Kramer-Johansen J, Wik L, Myklebust H, Barry AM, et al. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. Resuscitation 2006;71:137–45.
137. Edelson DP, Litzinger B, Arora V, Walsh D, Kim S, Lauderdale DS, et al. Improving in-hospital cardiac arrest process and outcomes with performance debriefing. Arch Intern Med 2008;168:1063–9.
138. Kramer-Johansen J, Myklebust H, Wik L, Fellows B, Svensson L, Sørebø H, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation 2006;71:283–92.
139. Hellevuo H, Sainio M, Nevalainen R, Huhtala H, Olkkola KT, Tenhunen J, et al. Deeper chest compression – more complications for cardiac arrest patients? Resuscitation 2013;84:760–5.
140. Zuercher M, Hilwig RW, Ranger-Moore J, Nysaether J, Nadkarni VM, Berg MD, et al. Leaning during chest compressions impairs cardiac output and left ventricular myocardial blood flow in piglet cardiac arrest. Crit Care Med 2010;38:1141–6.
141. Niles D, Nysaether J, Sutton R, Nishisaki A, Abella BS, Arbogast K, et al. Leaning is common during in-hospital pediatric CPR, and decreased with automated corrective feedback. Resuscitation 2009;80:553–7.
142. Fried DA, Leary M, Smith DA, Sutton RM, Niles D, Herzberg DL, et al. The prevalence of chest compression leaning during in-hospital cardiopulmonary resuscitation. Resuscitation 2011;82:1019–24.
143. Yannopoulos D, McKnite S, Aufderheide TP, Sigurdsson G, Pirrallo RG, Benditt D, et al. Effects of incomplete chest wall decompression during cardiopulmonary resuscitation on coronary and cerebral perfusion pressures in a porcine model of cardiac arrest. Resuscitation 2005;64:363–72.
144. Glatz AC, Nishisaki A, Niles DE, Hanna BD, Eilevstjonn J, Diaz LK, et al. Sternal wall pressure comparable to leaning during CPR impacts intrathoracic pressure and haemodynamics in anaesthetized children during cardiac catheterization. Resuscitation 2013;84:1674–9.
145. Beesems SG, Wijmans L, Tijssen JG, Koster RW. Duration of ventilations during cardiopulmonary resuscitation by lay rescuers and first responders: relationship between delivering chest compressions and outcomes. Circulation 2013;127:1585–90.
146. Jost D, Degrange H, Verret C, Hersan O, Banville IL, Chapman FW, et al. DEFI 2005 a randomized controlled trial of the effect of automated external defibrillator cardiopulmonary resuscitation protocol on outcome from out-of-hospital cardiac arrest. Circulation 2010;121:1614–22.
147. Cheskes S, Schmicker RH, Christenson J, Salcido DD, Rea T, Powell J, et al. Perishock pause: an independent predictor of survival from out-of-hospital shockable cardiac arrest. Circulation 2011;124:58–66.

148. Cheskes S, Schmicker RH, Verbeek PR, Salcido DD, Brown SP, Brooks S, et al. The impact of peri-shock pause on survival from out-of-hospital shockable cardiac arrest during the Resuscitation Outcomes Consortium PRIMED trial. Resuscitation 2014;85:336–42.
149. Christenson J, Andrusiek D, Everson-Stewart S, Kudenchuk P, Hostler D, Powell J, et al. Chest compression fraction determines survival in patients with out-of-hospital ventricular fibrillation. Circulation 2009;120:1241–7.
150. Sell RE, Sarno R, Lawrence B, Castillo EM, Fisher R, Brainard C, et al. Minimizing pre- and post-defibrillation pauses increases the likelihood of return of spontaneous circulation (ROSC). Resuscitation 2010;81:822–5.
151. Vaillancourt C, Everson-Stewart S, Christenson J, Andrusiek D, Powell J, Nichol G, et al. The impact of increased chest compression fraction on return of spontaneous circulation for out-of-hospital cardiac arrest patients not in ventricular fibrillation. Resuscitation 2011;82:1501–7.
152. Hinchey PR, Myers JB, Lewis R, De Maio VJ, Reyer E, Licatese D, et al. Improved out-of-hospital cardiac arrest survival after the sequential implementation of 2005 AHA guidelines for compressions, ventilations, and induced hypothermia: the Wake County experience. Ann Emerg Med 2010;56:348–57.
153. Olasveengen TM, Vik E, Kuzovlev A, Sunde K. Effect of implementation of new resuscitation guidelines on quality of cardiopulmonary resuscitation and survival. Resuscitation 2009;80:407–11.
154. Sayre MR, Cantrell SA, White LJ, Hiestand BC, Keseg DP, Koser S. Impact of the 2005 American Heart Association cardiopulmonary resuscitation and emergency cardiovascular care guidelines on out-of-hospital cardiac arrest survival. Prehosp Emerg Care 2009;13:469–77.
155. Steinmetz J, Barnung S, Nielsen SL, Risom M, Rasmussen LS. Improved survival after an out-of-hospital cardiac arrest using new guidelines. Acta Anaesthesiol Scand 2008;52:908–13.
156. Hostler D, Rittenberger JC, Roth R, Callaway CW. Increased chest compression to ventilation ratio improves delivery of CPR. Resuscitation 2007;74:446–52.
157. Abella BS, Edelson DP, Kim S, Retzer E, Myklebust H, Barry AM, et al. CPR quality improvement during in-hospital cardiac arrest using a real-time audiovisual feedback system. Resuscitation 2007;73:54–61.
158. Berg RA, Sanders AB, Milander M, Tellez D, Liu P, Beyda D. Efficacy of audio-prompted rate guidance in improving resuscitator performance of cardiopulmonary resuscitation on children. Acad Emerg Med 1994;1:35–40.
159. Bobrow BJ, Vadeboncoeur TF, Stolz U, Silver AE, Tobin JM, Crawford SA, et al. The influence of scenario-based training and real-time audiovisual feedback on out-of-hospital cardiopulmonary resuscitation quality and survival from out-of-hospital cardiac arrest. Ann Emerg Med 2013;62:47.e1–56.e1.
160. Chiang WC, Chen WJ, Chen SY, Ko PC, Lin CH, Tsai MS, et al. Better adherence to the guidelines during cardiopulmonary resuscitation through the provision of audio-prompts. Resuscitation 2005;64:297–301.
161. Lukas RP, Gräsner JT, Seewald S, Lefering R, Weber TP, Van Aken H, et al. Chest compression quality management and return of spontaneous circulation: a matched-pair registry study. Resuscitation 2012;83:1212–8.
162. Sainio M, Kämäräinen A, Huhtala H, Aaltonen P, Tenhunen J, Olkkola KT, et al. Real-time audiovisual feedback system in a physician-staffed helicopter emergency medical service in Finland: the quality results and barriers to implementation. Scand J Trauma Resusc Emerg Med 2013;21:50.
163. Sutton RM, Niles D, French B, Maltese MR, Leffelman J, Eilevstjønn J, et al. First quantitative analysis of cardiopulmonary resuscitation quality during in-hospital cardiac arrests of young children. Resuscitation 2014;85:70–4.
164. Kellum MJ, Kennedy KW, Barney R, Keilhauer FA, Bellino M, Zuercher M, et al. Cardiocerebral resuscitation improves neurologically intact survival of patients with out-of-hospital cardiac arrest. Ann Emerg Med 2008;52:244–52.
165. Kellum MJ, Kennedy KW, Ewy GA. Cardiocerebral resuscitation improves survival of patients with out-of-hospital cardiac arrest. Am J Med 2006;119:335–40.
166. Bobrow BJ, Ewy GA, Clark L, Chikani V, Berg RA, Sanders AB, et al. Passive oxygen insufflation is superior to bag-valve-mask ventilation for witnessed ventricular fibrillation out-of-hospital cardiac arrest. Ann Emerg Med 2009;54:656.e1–62.e1.
167. Mosier J, Itty A, Sanders A, Mohler J, Wendel C, Poulsen J, et al. Cardiocerebral resuscitation is associated with improved survival and neurologic outcome from out-of-hospital cardiac arrest in elders. Acad Emerg Med 2010;17:269–75.
168. Bobrow BJ, Clark LL, Ewy GA, Chikani V, Sanders AB, Berg RA, et al. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. JAMA 2008;299:1158–65.
169. Saïssy JM, Boussignac G, Cheptel E, Rouvin B, Fontaine D, Bargues L, et al. Efficacy of continuous insufflation of oxygen combined with active cardiac compression-decompression during out-of-hospital cardiorespiratory arrest. Anesthesiology 2000;92:1523–30.
170. Bertrand C, Hemery F, Carli P, Goldstein P, Espesson C, Rüttimann M, et al. Constant flow insufflation of oxygen as the sole mode of ventilation during out-of-hospital cardiac arrest. Intensive Care Med 2006;32:843–51.
171. White L, Rogers J, Bloomingdale M, Fahrenbruch C, Culley L, Subido C, et al. Dispatcher-assisted cardiopulmonary resuscitation: risks for patients not in cardiac arrest. Circulation 2010;121:91–7.
172. Haley KB, Lerner EB, Pirrallo RG, Croft H, Johnson A, Uihlein M. The frequency and consequences of cardiopulmonary resuscitation performed by bystanders on patients who are not in cardiac arrest. Prehosp Emerg Care 2011;15:282–7.
173. Moriwaki Y, Sugiyama M, Tahara Y, Iwashita M, Kosuge T, Harunari N, et al. Complications of bystander cardiopulmonary resuscitation for unconscious patients without cardiopulmonary arrest. J Emerg Trauma Shock 2012;5:3–6.
174. Tanaka Y, Nishi T, Takase K, Yoshita Y, Wato Y, Taniguchi J, et al. Survey of a protocol to increase appropriate implementation of dispatcher-assisted cardiopulmonary resuscitation for out-of-hospital cardiac arrest. Circulation 2014;129:1751–60.
175. Cappato R, Curnis A, Marzollo P, Mascioli G, Bordonali T, Beretti S, et al. Prospective assessment of integrating the existing emergency medical system with automated external defibrillators fully operated by volunteers and laypersons for out-of-hospital cardiac arrest: the Brescia Early Defibrillation Study (BEDS). Eur Heart J 2006;27:553–61.
176. Kitamura T, Iwami T, Kawamura T, Nagao K, Tanaka H, Hiraide A, et al. Nationwide public-access defibrillation in Japan. N Engl J Med 2010;362:994–1004.
177. Kitamura T, Iwami T, Kawamura T, Nitta M, Nagao K, Nonogi H, et al. Nationwide improvements in survival from out-of-hospital cardiac arrest in Japan. Circulation 2012;126:2834–43.
178. Mitani Y, Ohta K, Yodoya N, Otsuki S, Ohashi H, Sawada H, et al. Public access defibrillation improved the outcome after out-of-hospital cardiac arrest in school-age children: a nationwide, population-based, Utstein registry study in Japan. Europace 2013;15:1259–66.
179. Hallstrom AP, Ornato JP, Weisfeldt M, Travers A, Christenson J, McBurnie MA, et al. Public-access defibrillation and survival after out-of-hospital cardiac arrest. N Engl J Med 2004;351:637–46.
180. Berdowski J, Blom MT, Bardai A, Tan HL, Tijssen JG, Koster RW. Impact of onsite or dispatched automated external defibrillator use on survival after out-of-hospital cardiac arrest. Circulation 2011;124:2225–32.
181. Capucci A, Aschieri D, Piepoli MF, Bardy GH, Iconomu E, Arvedi M. Tripling survival from sudden cardiac arrest via early defibrillation without traditional education in cardiopulmonary resuscitation. Circulation 2002;106:1065–70.
182. Kuisma M, Castrén M, Nurminen K. Public access defibrillation in Helsinki–costs and potential benefits from a community-based pilot study. Resuscitation 2003;56:149–52.
183. Iwami T, Kitamura T, Kawamura T, Mitamura H, Nagao K, Takayama M, et al. Chest compression-only cardiopulmonary resuscitation for out-of-hospital cardiac arrest with public-access defibrillation: a nationwide cohort study. Circulation 2012;126:2844–51.
184. Culley LL, Rea TD, Murray JA, Welles B, Fahrenbruch CE, Olsufka M, et al. Public access defibrillation in out-of-hospital cardiac arrest: a community-based study. Circulation 2004;109:1859–63.
185. Fleischhackl R, Roessler B, Domanovits H, Singer F, Fleischhackl S, Foitik G, et al. Results from Austria's nationwide public access defibrillation (ANPAD) programme collected over 2 years. Resuscitation 2008;77:195–200.
186. Rea TD, Olsufka M, Bemis B, White L, Yin L, Becker L, et al. A population-based investigation of public access defibrillation: role of emergency medical services care. Resuscitation 2010;81:163–7.
187. Swor R, Grace H, McGovern H, Weiner M, Walton E. Cardiac arrests in schools: assessing use of automated external defibrillators (AED) on school campuses. Resuscitation 2013;84:426–9.
188. Weisfeldt ML, Sitlani CM, Ornato JP, Rea T, Aufderheide TP, Davis D, et al. Survival after application of automatic external defibrillators before arrival of the emergency medical system: evaluation in the resuscitation outcomes consortium population of 21 million. J Am Coll Cardiol 2010;55:1713–20.
189. Weisfeldt ML, Everson-Stewart S, Sitlani C, Rea T, Aufderheide TP, Atkins DL, et al. Ventricular tachyarrhythmias after cardiac arrest in public versus at home. N Engl J Med 2011;364:313–21.
190. Rea TD, Helbock M, Perry S, Garcia M, Cloyd D, Becker L, et al. Increasing use of cardiopulmonary resuscitation during out-of-hospital ventricular fibrillation arrest: survival implications of guideline changes. Circulation 2006;114:2760–5.
191. Berdowski J, Tijssen JG, Koster RW. Chest compressions cause recurrence of ventricular fibrillation after the first successful conversion by defibrillation in out-of-hospital cardiac arrest. Circ Arrhythm Electrophysiol 2010;3:72–8.
192. Sayre MR, Koster RW, Botha M, Cave DM, Cudnik MT, Handley AJ, et al. Part 5: adult basic life support: 2010 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Circulation 2010;122:S298–324.
196. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 4: adult basic life support. Circulation 2005;112:IV-18–34.
197. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 4: advanced life support. Resuscitation 2005;67:213–47.