Guidelines for pediatric cardiopulmonary resuscitation - 2015

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INTRODUCTION

During the sixties Dr. Peter Safar, an Austrian anesthetist working at the University of Pittsburgh (USA) published the first guidelines for cardiopulmonary resuscitation (CPR) standardization, substantially changing the prognosis of cardiopulmonary arrest (CPA) patients. Since that, CPR guidelines have been revised in numerous occasions under the leadership of the American Heart Association (AHA) and, during the last fifteen years, these guidelines reached international scope and acceptance, always incorporating advances from clinical and experimental research.

Review and Update Process

The last update of CPR Guidelines, published in 2015, was promoted by the International Liaison Committee on Resuscitation (ILCOR) in association with AHA and the participation of 250 medical and researcher experts from 39 countries, which revised more than 150 topics on the subject.

Revisions were performed according to two processes, namely: (1) GRADE (Grading of Recommendations, Assessment, Development and Evaluation: www.gradeworkinggroup.org), which is a highly structured review system based on evidences used to improve the consistency and quality of 2015 systematic reviews; and (2) SEERS (Systematic Evidence Evaluation and Review System), which is an internet platform developed by the AHA and used by reviewers to collectively discuss and propose conclusions.

The 2015 update of CPR guidelines was based on the recent version of AHA definitions for Classes of Recommendation and Level of Evidence (Table 1). It included 315 recommendations classified as Class I (78; 25%), Class II (217; 68%) and Class III (20; 7%). Likewise, three (1%) were based on Level of Evidence (LOE) A, 50 (15%) on LOE B-R (randomized studies), 46 (15%) on LOE B-NR (nonrandomized studies), 145 (46%) on LOE C-LD (based on limited data), and 73 (23%) in LOE C-EO (consensus of expert opinion).

The use of these processes established a new system for CPR guideline updates, which, from now on, will be continuously performed, and not every five years as before. In other words, these guidelines will be updated whenever a breakthrough is found.

Both the organization of the CPA care system and the Basic and Advanced Life Support and Post-Resuscitation Care were the most emphasized aspects and motives for the update of the 2010 CPR guidelines.

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Table 1. AHA Classes of Recommendation and Levels of Evidence.

<table>
<thead>
<tr>
<th>Class of Recommendation</th>
<th>Level of Evidence</th>
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<tr>
<td>Class I (Strong)</td>
<td>Level A: High-quality evidence from more than one randomized controlled trial (RCT); meta-analysis of high quality RCT; one or more RCT supported by high quality registration studies.</td>
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<tr>
<td>Class IIa (Moderate)</td>
<td>Level B-R: Moderate-quality evidence from one or more RCT; meta-analysis of high quality RCT.</td>
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<tr>
<td>Class IIb (Weak)</td>
<td>Level B-NR: Moderate-quality evidence from one or more well-designed, well-executed nonrandomized (NRS), observational or registry studies; meta-analysis of such studies.</td>
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<tr>
<td>Class III: No benefit (Moderate)</td>
<td>Level C-LD: Randomized or nonrandomized observational or registry studies with limitations of design or execution; meta-analysis of such studies; physiological or mechanistic studies in human subjects.</td>
</tr>
<tr>
<td>Class III: Damage (Strong)</td>
<td>Level C-EO: Consensus of expert opinion based on clinical experience</td>
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Adapted from American Heart Association new classification system for Classes of Recommendation and Level of Evidence. Class of Recommendation III was divided into two subclasses, namely: moderate (treatment used does not cause benefit neither harm) and strong (harmful when used). Levels of Evidence B and C were divided into two subgroups, according to evidence types and strength.

Care Systems and Quality Improvement

Every healthcare system requires fundamental elements to obtain good results, especially a well assembled structure and adequate processes. Structure involves people, equipment, education and data registry, while processes involve policies, protocols and procedures. The integrated operation of all these elements determines a scenario of continued improvements in people healthcare.

Therefore, the care system for CPA patients will be more efficient and achieve better results if it works in an integrated manner. It is known that survival after CPA depends on the early identification (trained people/procedures), on the immediate activation of the emergency response system (equipment/protocols) and on the quality of the CPR (education/policies) performed on the occasion. Also, quality improves to the extent that facts are repeated (data registry) and the system is repeatedly mobilized, correcting errors and improving results.

Recommendation

The 2015 CPR guidelines recommend special attention to two distinct CPR systems for CPA patient care: the in-hospital (IH) and extra-hospital (EH). There is even the suggestion of two survival chains to these systems, since each of them is associated with distinct structures and processes within their environments.

For EH CPA victims, the elements for the care will be in the community: lay bystanders should recognize the CPA, call for help and start CPR procedures until a Emergency Medical System (EMS) trained team arrives, takes responsibility for CPR and transports the patient to an emergency room or ICU for advanced and post-resuscitation care.

In-hospital (IH) CPA victims are supported not only by CPA prevention and surveillance systems (Rapid Response Team or Emergency Medical Team), but also are readily treated by a multidisciplinary team of trained professionals that provides high quality CPR, defibrillation when required, and advanced life support. The two systems are complex and, although the IH environment is more conducive to best outcomes, aspects such as organization, training and the ability to act in unpredictable and adverse conditions determine the outcomes in both of them.

In-hospital CPA

Rapid Response Teams (RRT) or Emergency Medical Teams work preventively and/or precociously in clinically deteriorating patients to prevent IH CPA using risk-rating systems, such as PEWS (Pediatric Early Warning System). These teams’ performances have proven to be effective in reducing CPA occurrence and mortality.

Recommendation

The 2015 CPR guidelines recommend the implementation of RRT and risk classification systems in general units where children with high-risk illnesses are cared for (Class IIb, LOE C-LD).

Hospitals should maintain well-trained teams to perform CPR, and these teams should include a physician experienced in resuscitation and with expertise in supervising other physicians during CPR training. This professional should conduct debriefings (reflections and discussions) after each CPR procedure, focusing on various domains: psychomotor skills, cognitive aspects, team working, and emotional aspects related to the staff and family.
Recommendation

The 2015 CPR guidelines consider reasonable that hospitals implement debriefing policies aimed at rescuers performance after each CPA IH, both in adults and children (Class Ila, LOE C-LD).

Extra-Hospital CPA

Numerous studies with EH CPA victims demonstrate the improvement in survival rates and neurological outcomes in communities that maintained programs of public access to automatic external defibrillator (AED).

Recommendation

The 2015 CPR guidelines recommend the implementation programs of public access to DEA in communities of individuals at risk for EH CPA (Class I, LOE C-LD).

The proper identification of a CPA victim by bystanders is an important aspect to be considered regarding the communication with EMT regulators. This identification provides immediate initiation of CPR procedure, performed by a layperson and guided by the regulator.

Recommendation

The 2015 CPR guidelines recommend that EMT regulators, besides obtaining event location information, consider if the patient is in CPA and guide the performance of early CPR accordingly (Class I, LOE C-LD).

Basic Pediatric Life Support

Some recommendations from the pediatric Basic Life Support (BLS) have been retained and others were re-emphasized in relation to the 2010 edition, including algorithms of Pediatric BLS and Pediatric Cardiac Arrest with one and with two or more rescuers, the comparison of the C-A-B versus the A-B-C initial sequences, the depth and frequency of thoracic compressions, and the “compressions only” CPR.

In 2015 CPR guidelines, algorithms for a single (Figure 1) and for two or more rescuers (Figure 2) were separated to better guide responders through CPR initial steps. The use of mobile phones in search for medical aid has been emphasized in these new algorithms, as this new technology allows a single rescuer to alert the EMT, providing faster CPR initiation. These new algorithms recommend pulse evaluation at the time of breathing, in a time no shorter than five seconds and no longer than ten seconds. Also, they emphasize the priority of the rapid obtainment of an AED in sudden CPA witnessed by its probable cardiac etiology.

High Quality Resuscitation

Recommendation

The 2015 CPR guidelines recommend the maintenance of five components for high-quality CPR:

- Ensure thoracic compressions at the adequate frequency (110-120/min);
- Ensure thoracic compressions at the adequate depth (4 to 6 cm);
- Allow thorax return to the rest position between compressions;
- Minimize interruptions between compressions; and
- Avoid excessive ventilation.

CPR initial sequence: C-A-B versus A-B-C

CPR initial sequence was revised, but no studies comparing the two sequences in human subjects were found. Studies in adult and children manikins suggest that the time to the first ventilation is retarded in only six seconds, and the compression start time is reduced.

Recommendation

The 2015 CPR guidelines recommend maintaining the C-A-B initial CPR sequence use over the A-B-C sequence (Class IIB, LOE C-EO).

Frequency and depth of thoracic compressions

Data from studies evaluating thoracic compressions in children were also insufficient. For this reason, experts based their reviews on evidences and recommendations for adult BLS, which also allows easier BLS training. The 2010 guidelines recommended a frequency of at least 100 thoracic compressions per minute for adult CPR. The 2015 guidelines incorporate new evidence showing the need of an upper frequency limit, above which resuscitation can be adversely affected.

Recommendation

The 2015 CPR guidelines, in the absence of pediatric data, recommend that adult BLS guidelines are followed for CPR in infants and children regarding thoracic frequency, i.e. 100-120 compressions per minute (Class IIa LOE C-E-O).

Evidences to review recommendations of thoracic compressions depth in children were also limited. It is also reasonable that rescuers perform chest compressions that depress the thorax in at least one third of its anteroposterior diameter in pediatric patients, not exceeding 6.0 cm in adolescents. A study with adult subjects showed that
Figure 1. Pediatric cardiac arrest BLS algorithm for the single rescuer - 2015 update.

Adapted from Atkins et al. Circulation 2015.
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Figure 2. Pediatric cardiac arrest BLS algorithm for two or more rescuers - 2015 update.

Recommendation

The 2015 CPR guidelines recommend that pediatric thoracic compressions depress the thorax in 1.5 inches (4.0 cm) on infants, and 2.0 inches (5.0 cm) in children (Class Ia LOE C-L-D). From puberty, the recommendation is the same as the adult, at least 5.0 cm but not deeper than 6.0 cm (Class I, LOE C-LD).

“Compressions only” CPR

In a large observational study in Japan, the use of “compressions only” CPR was associated with worse neurological survival at 30 days in pediatric EH CPA, compared to conventional CPR (compressions and ventilations). The nature of pediatric CPA, which is predominantly asphyxic, determines better outcomes when ventilations are associated with resuscitation efforts.
**Recommendation**

The 2015 CPR guidelines recommend that conventional CPR (15 or 30 compressions to two ventilations) should always be used in pediatric cardiac arrest (Class I, LOE B-NR).

**Thorax full recoil after each compression (adult BLS)**

On the 2015 systematic review in adults, experts sought evidence about full thorax recoil after compressions, compared with incomplete recoil. Full chest recoil occurs when the sternum returns to its neutral position during CPR decompression phase. Thorax return promotes a negative intrathoracic pressure that allows venous return and cardiopulmonary blood flow. Leaning on the thorax between compressions affects its return to the neutral position, increasing the intrathoracic pressure and reducing the venous return, coronary perfusion pressure and myocardial blood flow, potentially damaging the CPR outcome. The group of experts that reviewed pediatric BLS has not studied this aspect.

**Advanced airway ventilation in CPR**

The recommendation of advanced airway ventilation was evaluated in adult BLS. When the victim has an advanced airway during CPR, rescuers no longer offer cycles of 30 compressions to two ventilations (i.e., they do not interrupt thoracic compressions to ventilate). Instead, they apply ventilation every 6 seconds (10 per minute) while compressions are being performed. This represents a simplification from the 2010 guidelines, in order to standardize a single number to rescuers.

**Recommendation**

The 2015 CPR guidelines recommend that, in the presence of an advanced airway, ventilations are performed every 6 seconds (10/min) while compressions are being performed (Class IIb, LOE C-LD).

**Advanced Life Support in Pediatrics**

The review did not bring new recommendations for the Advanced Life Support in Pediatrics; however, there was a deepening of the existing ones. The 2015 guidelines provide information upon fluid reposition in febrile diseases, use of atropine as premedication in tracheal intubation, invasive monitoring of blood pressure in cardiopulmonary resuscitation adjustment and use of lidocaine and amiodarone in the treatment of ventricular fibrillation and pulseless ventricular tachycardia. However, most of these recommendations are classified as weak and with very poor quality of evidence.

**Fluids resuscitation in Septic Shock**

The mortality in septic shock has been decreasing in the past recent years, due to an increase in publications on the subject and the establishment of guidelines that systematizes measures such as oxygen therapy, early antibiotic administration, vasopressors and inotropes administration and hemodynamic monitoring. All these procedures are associated with rapid and early volume replacement.

Whether to prevent the progression of a compensated to a decompensated shock, or to reverse a decompensated shock, the use of fluids administration in septic shock has been widespread in pediatrics, based on observational studies. Following the 2010 guidelines, a large controlled-randomized clinical trial with African pediatric patients affected by acute severe febrile illness was published. Results showed a decrease in survival associated with massive blood volume expansions. Limited access to inotropic drugs and mechanical ventilation were described as characteristics from the place of the study, resulting in worse outcomes in patients who received large fluid boluses.

**Recommendation**

The 2015 CPR guidelines recommend that the initial administration of 20ml/kg fluid bolus for infants and children in shock is acceptable (Class IIa, LOE C-LD), including in serious condition such as dengue and malaria (Class IIb, LOE B-R). However, fluid administration should be careful in places with limited access to mechanical ventilation and inotropic support (Class IIb, LOE B-R). It is important to always reevaluate the patient after each fluid administration, and always consider associated conditions such as malnutrition and anemia, besides local resources (Class I, LOE C-EO).

In most of the reviewed studies, no benefits from colloid in relation to crystalloid use were found. Nevertheless, in one study with patients in shock due to dengue, authors observed better outcomes regarding time for shock recovery in patients receiving colloid.

**Atropine as premedication for emergency tracheal intubation**

Bradycardia due to hypoxia, vagal response to laryngoscopy, positive pressure ventilation, and pharmacological effect of some medications such as succinylcholine or fentanyl, is a common observation in emergency intubation. Administration of atropine in order to avoid bradycardia during this procedure has been recommended. Evidences for this conduct have been based on observational studies, some extrapolated from experience of elective intubation during surgical procedures. Evidences are conflicting regarding the...
decrease in arrhythmia or post-intubation shock incidences associated with the use of atropine as premedication in emergency intubation\textsuperscript{14,15}. An atropine minimum dose of 0.1mg IV was recommended after the report of paradoxical bradycardia on very small infants who had received low doses of atropine\textsuperscript{16}. However, in two recent case series publications, doses lower than 0.1mg were used without patients developing paradoxical bradycardia, suggesting this treatment is safe and effective\textsuperscript{14,17}.

**Recommendation**

The 2015 CPR guidelines consider that results on atropine use as intubation premedication in infants and children to avoid paradoxical bradycardia and other arrhythmias are conflicting. Its use may be considered in increased-risk situations, such as the administration of succinylcholine (Class IIb, LOE C-LD). Doses below 0.1 mg may be considered for atropine use in emergency intubation (Class IIb, LOE C-LD).

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**Pre-arrest care of infants and children with myocarditis or dilated cardiomyopathy**

In 2015 revision, experts found no evidence in the literature regarding the best strategy for infants and children with myocarditis or dilated cardiomyopathy care upon CPA imminence. Observational studies have been reporting good results on the use of extracorporeal membrane oxygenation (ECMO) in children with acute fulminant myocarditis.

**Recommendation**

The 2015 CPR guidelines suggest that ECMO can considered in fulminating acute myocarditis patients who have imminent risk of CPA (Class IIb, LOE C-EO).

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**Cardiopulmonary reanimation with ECMO (ERCP) in pediatric-in-hospital CPA**

Observational studies have not shown better results for ECMO compared to conventional CPR in intra-hospital environment (36-41). In a retrospective review, authors found better outcomes associated with ERCP in heart disease patients, compared to patients without heart disease.

**Recommendation**

The 2015 CPR guidelines state that the use of ERCP may be considered for pediatric patients with heart disease that presents CPA in an in-hospital environment, where there are established ECMO protocols, with expertise and appropriate material (Class IIb, LOE C-LD).

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**Exhaled CO\textsubscript{2} monitoring for guiding CPR quality and hemodynamic monitoring during CPR**

The 2010 guidelines recommended that, when patients showed an exhaled CO\textsubscript{2} partial pressure consistently below 15 mmHg, efforts to improve CPR quality should be provided. In the 2015 review, no evidence suggesting the association between exhaled CO\textsubscript{2} monitoring and better CPA outcomes was found in the pediatric literature.

**Recommendation**

The 2015 CPR guidelines state that CO\textsubscript{2} monitoring may be considered for evaluation of thoracic compression quality, but specific values to guide therapy have not been established for pediatric patients (Class IIb, LOE C-LD).

For patients submitted to invasive hemodynamic monitoring during CPA, it may be acceptable to use a curve wave and blood pressure for guiding CPR quality (Class IIb, LOE C-DE). Specific blood pressure target values during CPR have not been established in children.

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**Vasopressors during CPA**

Vasopressors administration during CPA can restore spontaneous circulation by improving coronary perfusion with subsequent maintenance of cerebral perfusion. However, this treatment may cause vasoconstriction with increase in oxygen use as an undesired effect, which could be deleterious. There are no pediatric studies that demonstrate the effectiveness of any vasopressor in CPA.

The 2015 CPR guidelines consider reasonable the administration of epinephrine during CRA (Class IIa, LOE C-LD).

**Administration of amiodarone and lidocaine for ventricular fibrillation and pulseless ventricular tachycardia**

Based on pediatric case series studies or studies with adults subjects with short follow-up, 2005 and 2010 guidelines recommended the preferential use of amiodarone over lidocaine in the treatment of pulseless ventricular tachycardia and ventricular fibrillation. A further pediatric study\textsuperscript{18} showed good results with the use of lidocaine. This drug was associated with a significant increase in the probability of post CRA recovery.

**Recommendation**

The 2015 CPR guidelines recommend that both lidocaine and amiodarone may be used in refractory shock for ventricular fibrillation or pulseless ventricular tachycardia (Class IIb, LOE C-LD).

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**Energy dose for defibrillation**

**Recommendation**

The 2015 CPR Guidelines maintained the recommendation of 2 to 4 J/kg initial dose for both monophasic and biphasic defibrillation in CPA by ventricular fibrillation.
or pulseless ventricular tachycardia (Class IIa, LOE C-LD). For refractory shock, subsequent 4 J/kg doses should be considered (Class IIb, LOE C-EO) and gradual increases in energy levels may be used in subsequent doses, not exceeding 10 J/kg or the maximum dose for adults (Class IIb, LOE C-LD).

Post-resuscitation care
There were no substantial changes regarding recommendations for post-resuscitation in relation to the previous edition. Most emphasized points for care after the return of spontaneous circulation (ROSC) refers to temperature control, hemodynamic support and control of oxygenation levels in the tissues.

Temperature control
Fever in post-CPA patients is common and is associated with worse outcomes. The 2010 recommendations suggested aggressive fever control in all patients and therapeutic hypothermia for some patients. However, there is no evidence to support the use of hypothermia post-CPA in children.

Recommendation
The 2015 CPR guidelines recommend the continuous monitoring of body temperature (Class I LOE B-NR) and aggressive fever treatment, when present, (Class I LOE B-NR) in infants and children who remain comatose after a CPA. In comatose children resuscitated by PCREH, keep five days of normothermia (36°C to 37.5°C) or two days of initial continuous hypothermia (32°C to 34°C), followed by three days of normothermia (Class IIa LOE B-R). For children who remain comatose after PCRIH, hypothermia is not recommended and normothermia should be maintained.

Oxygenation Control
Experimental studies suggest that hyperoxia after ROSC can cause oxidative tissue damage. An observational study of children victims of IH and EH CPA demonstrated that normoxemia (PaO₂ between 60 and 300 mm Hg) results in better patient survival compared to hyperoxia (PaO₂ > 300 mm Hg) after ROSC.

Recommendation
The 2015 CPR guidelines recommend that hemoglobin saturation be maintained between 94 and 99% (Class IIb LOE B-NR), avoiding both hypoxemia and hyperoxia after CPA. Hypercapnia and hypocapnia should also be avoided (Class IIb LOE C-LD).

BIBLIOGRAPHY RECOMMENDED

BIBLIOGRAPHY CONSULTED


