A Review of Compression, Ventilation, Defibrillation, Drug Treatment, and Targeted Temperature Management in Cardiopulmonary Resuscitation

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Abstract

Objective: Important studies of cardiopulmonary resuscitation (CPR) techniques influence the development of new guidelines. We systematically reviewed the efficacy of some important studies of CPR.
Data Sources: The data analyzed in this review are mainly from articles included in PubMed and EMBASE, published from 1964 to 2014.
Study Selection: Original articles and critical reviews about CPR techniques were selected for review.
Results: The survival rate after out-of-hospital cardiac arrest (OHCA) is improving. This improvement is associated with the performance of uninterrupted chest compressions and simple airway management procedures during bystander CPR. Real-time feedback devices can be used to improve the quality of CPR. The recommended dose, timing, and indications for adrenaline (epinephrine) use may change. The appropriate target temperature for targeted temperature management is still unclear.
Conclusions: New studies over the past 5 years have evaluated various aspects of CPR in OHCA. Some of these studies were high-quality randomized controlled trials, which may help to improve the scientific understanding of resuscitation techniques and result in changes to CPR guidelines.

Key words: Cardiopulmonary Resuscitation; Defibrillation; Epinephrine; Ventilation

Introduction

Out-of-hospital cardiac arrest (OHCA) is usually an unexpected and tragic event. Bystanders often find it upsetting to witness an active person collapsing and becoming lifeless, especially young bystanders. Cardiopulmonary resuscitation (CPR) can save lives, and has been practiced since about 200 B.C. Current CPR techniques include mouth-to-mouth rescue breathing (Safar), chest compressions (Kouwenhoven), and defibrillation (Lown). The International Liaison Committee on Resuscitation and American Heart Association (AHA) published guidelines for CPR and emergency cardiovascular care in 2000, 2005, and 2010. Over the past 50 years, the rates of return of spontaneous circulation (ROSC) and survival after CPR have been disappointing. In the United States, the rate of survival until hospital admission after OHCA was 26.3% between 2005 and 2010, and only 9.6% of patients are able to be discharged from hospital.

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Compression and Ventilation

Chest compression or abdominal compression?

In the 2010 AHA guidelines, rapid initiation of effective chest compressions was upheld as the most important aspect of effective resuscitation in patients with cardiac arrest. Although some studies found that rhythmic abdominal compression-CPR was superior to chest compression-CPR in terms of pressure and ventilation metrics, abdominal compression-CPR resulted in less carotid artery flow and longer delay until ROSC rises. Studies of alternative CPR techniques require evaluation of the resulting perfusion of vessels supplying the heart, brain, and other vital organs.[1] Hand-only CPR is recommended in OHCA, especially in adults, because several important studies found that layperson hand-only CPR was associated with better survival after OHCA compared to conventional CPR.[2-4]

Feedback systems and new devices

Performance of high-quality CPR is important, including achievement of effective chest compressions and minimization of the intervals between stopping chest

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compressions, opening the airway and performing defibrillation. Real-time and other feedback systems can help to improve the quality of CPR.[5,6]

A randomized crossover trial included 24 health care professionals performing continuous chest compression CPR for 10 min with a CPRO device and conventional manual CPR. Studies found using CPR devices can reduce rescuer fatigue and pain during continuous chest compressions, resulting in a higher quality of CPR in simulated environments. However, a systematic review included 10 studies found insufficient evidence to support or refute the use of mechanical CPR devices in OHCA settings or during ambulance transport.[7] The LINC randomized clinical trial which included 2589 patients with OHCA conducted between 2008 and 2013 in 4 Swedish, 1 British, and 1 Dutch ambulance services and their referring hospitals found that mechanical CPR according to the present guidelines did not result in improved effectiveness compared with manual CPR.[8] But CPR devices can provide a reliable alternative to manual CPR in a moving ambulance, reduce human resource requirements, and improve safety for emergency medical services (EMS) personnel.[9] Use of alternative CPR techniques and devices may improve hemodynamic parameters and short-term survival when used by well-trained providers in selected patients.

Simple ventilation procedures are effective

The 2010 AHA guidelines recommend that trained rescuers should deliver rescue breathing using mouth-to-mouth or bag-mask techniques to provide oxygenation and ventilation.[10] However, there is an ongoing debate regarding the optimal procedures for further ventilation, such as bag-mask ventilation and the use of endotracheal tubes, supraglottic airway devices, and the passive oxygenation.[11] Previously, all resuscitation protocols recommended early tracheal intubation as an important aspect of prehospital advanced life support. In the last decade, however, less invasive methods have been preferred for airway management in adult OHCA patients. The 2010 European Resuscitation Council guidelines recommend prehospital tracheal intubation only if medical personnel with competent intubation skills are present, and only with minimal interruption of chest compressions.[11,12] The 2010 AHA guidelines recommend using the airway management device most familiar to the rescuer, and suggest that use of a supraglottic airway device may be as effective as bag-mask ventilation or tracheal intubation.[13] A simple method of airway management like bag-mask ventilation is recommended for OHCA. However, two recent studies found that the use of the laryngeal mask airway was probably associated with lower rates of neurologically intact survival than other methods of airway management.[14,15]

Defibrillation

Cardiopulmonary resuscitation first versus shock first

Early defibrillation is critical for survival after adult sudden cardiac arrest for several reasons: The most frequent initial rhythm is ventricular fibrillation (VF), the most effective treatment for VF is defibrillation, the probability of successful defibrillation diminishes rapidly over time, and VF tends to deteriorate to asystole over time.[16] The 2010 AHA guidelines recommend integration of CPR and automated external defibrillator (AED) use, to give the patient the best chance of survival. When there are two or more rescuers present, one rescuer should immediately start CPR while the other activates the emergency response system and prepares the defibrillator. The Cardiac Arrest Registry to Enhance Survival surveillance from 2005 to 2010 found that only 33.3% of OHCA patients received bystander CPR, and an AED was only used in 3.7% of cases by bystanders before the arrival of EMS providers.[17]

Recent research findings indicate that defibrillation before CPR increases the rate of ROSC. After a few minutes of VF, the oxygen supply and metabolic substrates of the myocardium are exhausted. A period of chest compressions before delivering a shock can deliver oxygen and metabolic substrates to the myocardium, thereby increasing the probability of a shock terminating VF and inducing ROSC.[18] However, the optimal period of CPR before defibrillation is unclear. The 2005 AHA guidelines recommended that EMS personnel should perform CPR for 2 min before the first analysis of cardiac rhythm. This recommendation was changed in the 2010 AHA guidelines, which state that there is inconsistent evidence to support or refute such a delay in the analysis of cardiac rhythm.[16] A recent study by Stiell *et al*.[19] found no difference in the outcome after OHCA between a brief period (30–60 s) or a longer period (180 s) of EMS-administered CPR before the first analysis of cardiac rhythm. The Resuscitation Outcomes Consortium PRIMED trial found that shorter peri-shock pauses were significantly associated with a higher likelihood of survival in patients with cardiac arrest who presented with a shockable rhythm.[20] Future advances in CPR education and technology should focus on minimizing peri-shock pauses. Longer peri-shock pauses were independently associated with a lower rate of survival to hospital discharge.[21] Future guidelines may include recommendations regarding peri-shock pause times.

One-shock protocol is effective

Two human studies (conducted in 2006 and 2008) compared a one-shock protocol with a three-stacked-shock protocol for the treatment of VF cardiac arrest,[22,23] and found that the one shock protocol was associated with a significant survival benefit compared with three-stacked-shock protocols. Almost all studies found that lower-energy biphasic waveform shocks had a higher or equivalent success rate for termination of VF than monophasic waveform shocks. The 2010 AHA guidelines suggest that it is reasonable to use a one-shock protocol for VF, preferably with a biphasic waveform shock, followed immediately by CPR.[16]

Drugs

Adrenaline (epinephrine) use may change

Adrenaline is the primary drug administered during CPR to reverse cardiac arrest. Adrenaline can increase cerebral perfusion pressure and coronary perfusion during CPR via alpha-1-adrenoceptor agonist effects. However, the dose, timing, and indications for adrenaline use are based on limited evidence. Initial guidelines for the treatment of cardiac arrest recommended administration of intracardiac adrenaline (0.5 mg) or high-dose intravenous adrenaline (10 mg), repeating with larger doses if required.[24] The 2010 AHA guidelines recommend administration of 1 mg of intravenous or intraosseous adrenaline every 3–5 min for adult cardiac arrest. If intravenous/intraosseous access is delayed or cannot be established, adrenaline may be given endotracheally at a dose of 2–2.5 mg.[13] However, recent research found that less frequent adrenaline use was associated with improved survival after OHCA.[25] The dose of adrenaline used during CPR has decreased over recent years.

The first randomized controlled trial of adrenaline use compared high-dose adrenaline (10 mg) with placebo after in-hospital cardiac arrest or OHCA, and found no difference in short- or long-term survival between the two treatment groups.[26] Another randomized trial compared use of 1 mg doses of adrenaline with placebo, and found better short-term survival in the adrenaline group but no significant difference in long-term survival between the two groups, and could not exclude the possibility of harm from adrenaline use.[27] Experimental studies suggest that the adrenaline impairs cerebral macrovascular[28] and microvascular blood flow,[29,30] increases ventricular arrhythmias, and increases myocardial dysfunction after ROSC.[31] However, no suitable substitute for adrenaline has been found. Several animal experiments found that the use of vasopressin resulted in improved survival compared with the use of adrenaline in asphyxial cardiac arrest models.[32,33] Studies comparing the use of a combination of vasopressin, steroids, adrenaline compared with adrenaline alone,[34] and of cytidine diphosphate choline compared with adrenaline,[35] did not find better outcomes in the adrenaline groups. For in-hospital cardiac arrest, the rate of ROSC is significantly higher when vasopressin is used compared with epinephrine. A subgroup meta-analysis found that the rates of ROSC, survival to hospital admission, survival to hospital discharge, and favorable neurological outcome may increase with the use of four to five boluses of vasopressin titrated to the desired effect, but no beneficial effect of vasopressin use was observed in unselected cardiac arrest patients.[36] A Chinese study compared the use of adrenaline with Shen-Fu injection (a Chinese herbal medicine) in a porcine model of prolonged cardiac arrest and found that Shen-Fu injection was associated with better oxygen metabolism and hemodynamic status.[37] The available clinical data indicate that administration of adrenaline during CPR can increase short-term survival, but may have no benefit or even a harmful effect on long-term survival and neurological functional recovery. Prospective trials are needed to determine the optimal dose, timing, and patient selection for use of adrenaline during the treatment of cardiac arrest.[38]

Targeted Temperature Management

For the protection of the brain and other organs, hypothermia is a helpful therapeutic approach in patients who remain comatose (usually defined as a lack of meaningful response to verbal commands) after ROSC. Targeted temperature management (TTM) has been investigated experimentally and used clinically for over 100 years. TTM is recommended in the 2010 AHA guidelines, and its use has been extended to OHCA with arrhythmia other than VF as well as to in-hospital cardiac arrest.[39] Although a Cochrane review supports these guidelines,[40] some researchers have suggested an urgent need for further trials to confirm or refute the current recommendations.[41] In 2002, two important clinical trials were published in the New England Journal of Medicine, which compared patients who remained unconscious after ROSC and received TTM (32–34°C for 12–24 h) with those who remained unconscious after ROSC and received standard treatment.

One study included 77 subjects who were randomly assigned to treatment with hypothermia (with temperature reduced to 33°C within 2 h after the ROSC and maintained for 12 h) or normothermia. The other multicenter trial was prepared by Hypothermia after Cardiac Arrest Study Group, 75 of the 136 patients in the hypothermia group had a favorable neurologic outcome, as compared with 54 of 137 in the normothermia group.

These trials showed a significant improvement in neurological function and survival in patients treated with TTM.[42,43] In 2011, a research team from the American College of Chest Physicians reviewed studies of TTM, and strongly recommended use of TTM to a target of 32–34°C in OHCA patients who first presented with VF or pulseless ventricular tachycardia and remained unconscious after ROSC.[44] However, Nielsen *et al*.[45] found that TTM to a target of 33°C did not confer any benefit compared with a target of 36°C in 939 OHCA patients who remained unconscious after ROSC. The optimal target temperature and optimal timing of achieving the target temperature remain unclear. Abella *et al*.[46] used a murine cardiac arrest model to compare cooling during cardiac arrest and before ROSC (intra-arrest hypothermia) with post-ROSC cooling, and found that intra-arrest cooling had a significant survival benefit compared with post-ROSC cooling or normothermic resuscitation. It remains unclear which cooling measures are beneficial to cardiac arrest patients. A study from the Weil Institute of Critical Care Medicine of America found that both intra-arrest head cooling and delayed surface cooling improved post-resuscitation myocardial function, with the most beneficial effect observed when head cooling was initiated during CPR.[47] They also found that initiation of intranasal cooling at the start of CPR significantly improved the success of resuscitation in a porcine model of prolonged cardiac arrest. This may be because hypothermia results in reduced brain damage.[48]

Conclusion

Many studies over the past decade have evaluated various aspects of CPR in OHCA. Some of these studies were high-quality randomized controlled trials, which helped to improve the scientific understanding of resuscitation techniques and resulted in changes to CPR guidelines. For example, the previous airway-breathing-circulation basic life support algorithm for adults with cardiac arrest has changed to circulation-airway-breathing,[49] and postcardiac arrest care has recently attracted more attention in accordance with the development of cardiocerebral resuscitation philosophies.[50] The rates of ROSC and survival after CPR are still disappointing. According to the 2012 National Utstein Report, the overall rate of ROCS after OHCA was 59% and the overall rate of survival after OHCA was 10%. The survival rate was 3.75 times higher after witnessed OHCA (15%) than after unwitnessed OHCA (4%). The survival rate after witnessed and shockable OHCA with bystander CPR was 37%, but only 4% of bystanders used an AED. A Japanese study also found that only 0.7% of bystanders used an AED.[51]

Although technological advances like AED development have contributed to increased survival rates after cardiac arrest, no initial intervention will be performed unless bystanders are ready, willing, and able to act. It is, therefore, necessary to increase public education regarding CPR techniques in addition to studying the effectiveness of various interventions. Education of public officials and community members regarding the importance of increasing the rate of bystander CPR and promotion of AED use by lay and professional rescuers, are important aspects of increasing survival rates.

Compression, ventilation, and defibrillation are the cornerstone of CPR. Uninterrupted chest compressions, simple and effective airway management procedures during bystander CPR will continue to be highly recommended. Although epinephrine is mostly used for successful ROSC, the influence of this drug on recovery during the postcardiac arrest phase is debatable, and recently a few studies found that use of epinephrine was consistently associated with a lower chance of survival after return to ROSC. The recommended dose, timing, and indications for epinephrine use may be changed. Future studies will focus on if and how epinephrine may provide long-term functional survival benefit. Strongly recommendation of using TTM and CPR auxiliary device will need support of new studies.

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