

Review Article

Cardiopulmonary Resuscitation by Chest Compression Alone: A Reality Check

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Cardiac arrest is described as the sudden cessation of effective cardiac pumping function due to either ventricular fibrillation or pulseless ventricular tachycardia or ventricular asystole (electrical or mechanical).¹ A study by Zheng et al, in United States residents aged ≥ 35 years, showed that sudden cardiac death represented 63% of all cardiac deaths, causing 300,000 to 400,000 deaths annually.²

Cardiopulmonary resuscitation (CPR) is an important element in the "chain of survival" for the treatment of patients with cardiac arrest. Modern CPR was developed in the late 1950s and early 1960s. In early 1960 Drs. Kouwenhoven, Knickerbocker and Jude discovered the benefit of chest compression to achieve a small amount of artificial circulation. Later in 1960, mouth-to-mouth and chest compression were combined to form CPR, similar to the way it is practiced today.³ Since then the guidelines for CPR have evolved through six national conferences with the most recent held in 2005.

The aim of CPR is to deliver oxygen to vital organs until a spontaneous circulation can be achieved. The earlier that CPR is started, the better the outcome.⁴⁻¹¹ Early CPR and defibrillation increase the

likelihood of survival to discharge from the hospital.¹²⁻¹⁴ Delay in time to defibrillation for more than 10 min renders CPR ineffective.¹⁵ Delay in provision of CPR and defibrillation may increase the likelihood of death by 1.1 times per minute of delay.¹⁶

Bystander CPR is also a strong predictor of long term survival.¹⁷⁻²⁴ Nonetheless, reports have shown that bystander CPR was attempted in less than a third of patients who collapsed.²⁵⁻²⁸ Surveys have identified the reluctance of bystanders to undertake mouth-to-mouth ventilation as a substantial barrier to CPR attempts.²⁹⁻³⁰ When asked anonymously, most individuals confide they would prefer not to do mouth-to-mouth breathing for a stranger.³¹⁻³³ Another barrier to bystanders attempting CPR is the complexity of the technique as presently taught.^{34,35} Handley et al found that, by decreasing the number of sequential steps asked of laypersons in responding to an unconscious victim, the remaining steps were better remembered and performed.³⁶

These observations prompted the need for simpler CPR techniques that would be easy to learn, retain and be correctly performed by lay rescuers. One of the most important and simultaneously intriguing

steps towards this direction was the exclusion of mouth-to-mouth ventilation from the CPR equation. This article provides a brief review of the latest CPR guidelines and comments on the current literature concerning the use of cardiac-only resuscitation.

Pathophysiology

Weisfeldt and Becker proposed a 3-phase time-sensitive model of cardiac arrest.³⁷ These phases are the electrical, circulatory, and metabolic. During the electrical phase of cardiac arrest, defibrillation is the most effective treatment, whereas in the circulatory phase, good quality CPR gains increasing importance, along with defibrillation. In the third and final metabolic phase, global ischemic injury occurs and therapeutic strategies that focus on metabolic derangements are critical. Early defibrillation is re-emphasized as an essential therapy for the electrical phase of cardiac arrest. Patients who received defibrillation within 3 min of collapse had a 75% hospital discharge rate.¹ However, the majority of pre-hospital cardiac arrests are treated in the circulatory phase, during which there is a need for immediate compressions to generate blood flow and partially replenish the membrane's energy required for generation of an organized rhythm.

Current CPR guidelines

Compressions-decompressions

The latest guidelines published by both the European Resuscitation Council (ERC) and the American Heart Association (AHA) include substantial changes to the algorithms for basic life support and advanced cardiovascular life support.^{19,20} The new guidelines focus on more compressions and fewer ventilations. This change was prompted by observations that rescue breaths caused unacceptably long interruptions during chest compressions, with patients receiving only 39 to 49 compressions per minute.^{38,39} The compression to ventilation ratio was increased from 15:2 to 30:2 in order to provide fewer interruptions of compressions for ventilation. Recognizing the importance of compressions during CPR, current guidelines recommend pushing 'hard and fast'. A depth of 1.5-2 in. (5 cm) is considered adequate, while a rate of 100 compressions/min is preferable, as lower rates decrease forward blood flow. The generation of blood flow during compression results from an increase in intrathoracic pressure (thoracic pump theory), the

mechanical effect of compressing the heart between the sternum and the spine (cardiac pump theory), and the cardiac valvular system, which allows mainly unidirectional flow. However, even in the best of circumstances, the generated cardiac output is 20% of normal. Moreover, every time compressions are stopped, it takes a significant amount of time to re-establish adequate aortic and coronary perfusion pressures.⁴⁰ Hence, interruptions should be kept to a minimum because they can be extremely detrimental: no compressions means no perfusion. Towards this notion, pulse checks should not last more than 10 s.

Newly emphasized is the importance of the decompression phase. The negative intrathoracic pressure generated by the elastic recoil properties of the thorax promotes venous return to the heart, consequently increasing preload for the next compression cycle. Incomplete decompression is a common mistake that decreases blood flow to the heart and brain during CPR. Hyperventilation, fatigue and ineffective technique, such as inappropriate hand positioning, can result in incomplete chest wall recoil.

Ventilations

As mentioned above, the guidelines stress the importance of reducing the frequency of ventilation during CPR. It is currently proposed that only two breaths should be given after 30 continuous compressions, with a rate of no more than 8-10 breaths/min. Another issue of significant importance is that each time the intrathoracic pressure is increased with a positive pressure ventilation, venous return to the heart is inhibited and intracranial pressure is increased.⁴¹ In order to minimize this phenomenon, each breath should be delivered with a tidal volume of only 500 cc and over a period of only 1 s.

Defibrillation

Defibrillation interrupts fibrillatory electrical activity in the heart and allows the normal pacemakers to produce an effective rhythm to ensure systemic perfusion.⁴² It is the treatment of choice for pulseless ventricular tachycardia or ventricular fibrillation, but it is not recommended for ventricular asystole (electrical or mechanical).

Immediate defibrillation is the best first response for cardiac arrest victims. Nonetheless, the AHA guidelines distinguish between witnessed and unwitnessed cardiac arrest (in which the duration is

unknown). In the latter situation it is recommended that 2 min of CPR should be provided prior to defibrillation.

Another issue of great interest was the changes in the sequence of defibrillation. The 2000 guidelines had recommended the use of 3 stacked shocks, with the pulse being checked after each shock. However, published data have shown that this algorithm causes inappropriate delay in CPR.^{43,44} Considering the pivotal role of the latter in the resuscitation sequel, current guidelines recommend resumption of immediate CPR after the first shock.^{18-19,42} At the end of each shock/CPR cycle the pulse is checked. In case of shockable rhythm, CPR is continued while the defibrillator is charging. The second shock is given only after 5 cycles of CPR, which should take approximately 2 minutes.

With regard to the electrical waveforms used, it appears that biphasic shocks have higher success rates with the first shock than do monophasic.⁴⁵⁻⁴⁶ Furthermore, organized rhythms may last longer when defibrillation is performed through a device that uses the biphasic waveform.⁴³ As far as the appropriate energy level is concerned the current guidelines recommend 360 J when monophasic waveform defibrillators are used,⁴⁷ 120 J for biphasic rectilinear waveform, and 150-200 J for biphasic truncated exponential waveform devices. Subsequent shocks may be given at the same or higher energy levels.

Research data on cardiac-only resuscitation

Animal studies

Animal investigations have provided us with results in favor of the use of chest-compression only CPR (CO-CPR); nevertheless, published data to date remain inconclusive.⁴⁸⁻⁵⁴ In favor of the use of CO-CPR, a study by Noc and Weil found that positive pressure ventilation was not necessary for successful resuscitation or 48-hour survival from ventricular fibrillation cardiac arrest.⁵⁵ Similar results were found by the University of Arizona Resuscitation Research Group, in a series of experiments exploring the possibility of bystander CO-CPR.^{40,48-51} In one of their reports they highlight the adverse hemodynamic effects of interrupting chest compressions for rescue breathing during CPR for ventricular fibrillation.⁴⁰ According to their study, the median left ventricular myocardial blood flow was markedly lower during early conventional CPR than CO-CPR. The same research

group, using a 30:2 compression:ventilation ratio with 16-second pauses in compressions to provide 2 rescue breaths, recently demonstrated that the administration of continuous chest compressions without assisted ventilations resulted in significantly better 24-hour post-resuscitation, neurologically normal survival than did the use of conventional bystander CPR.⁵⁷ In contrast to the above, studies on porcine asphyxial cardiac arrest models have shown that the use of chest compressions with rescue breathings are superior to the use of chest compression alone in terms of clinical outcome.^{58,59}

Human studies

In accordance with the previously described animal studies, several clinical trials have shown that CO-CPR is at least as effective as conventional CPR.^{10,24,60} Hallstrom et al showed that the outcome after CPR with chest compressions alone is similar to that after chest compressions with mouth-to-mouth ventilation.⁵⁴ Similarly, a recent study of out-of-hospital cardiac arrest victims in Singapore demonstrated that there was no significant difference in survival to discharge between patients who received CO-CPR and those given standard CPR.⁶¹ Furthermore, according to the SOS-KANTO study group, cardiac-only resuscitation is not only equivalent but superior to conventional bystander CPR in terms of neurological benefit.⁶² In agreement with the above, Iwami and colleagues, in a prospective observational study, found similar outcomes in cardiac-only and conventional CPR groups, at least for those with arrest intervals ≤ 15 min.⁶³ For very-long-duration arrests (>15 min), neurologically favorable 1-year survival was greater in the conventional CPR group, though there were few survivors in this subgroup, regardless of the type of bystander CPR. In contrast, Bohm et al found no difference in 1-month survival between groups, regardless of whether the ambulance response time was less than or greater than 8 minutes.⁶⁴ Although the above findings appear to be rather promising, it should be emphasized that only the study by Hallstrom was randomized. Two large prospective, randomized trials comparing cardiac-only and conventional CPR for subjects with out-of-hospital cardiac arrest are currently recruiting participants.⁶⁵

Physiologic mechanisms

Several mechanisms might account for the efficacy of

cardiac-only resuscitation. Many studies have suggested that ventilation is not essential during the initial 12 min of resuscitation with untreated arrest intervals of less than 6 min.^{55,66} According to Chandra et al, there is generally sufficient oxygen within the blood before cardiac arrest so that, with the limited circulation (the most that even the best chest compressions can provide), reasonable oxygen saturation persists for at least 10 min and maybe even longer.⁶⁷ Measured minute ventilation and arterial oxygenation decrease after 4-10 min of resuscitation, irrespective of attempts at ventilation.^{56,66} Furthermore, ventilation may occur during CO-CPR through active and passive mechanisms. After a non-hypoxic cardiac arrest, patients usually continue to breath actively for some short period, before the respiratory centre in the brain ceases to function because of hypoxia. The breathing pattern is abnormal and manifests as gasping. Gasping respirations have been observed in animal and human studies. In animal studies, significant tidal volumes have been documented and are associated with an increased chance of successful resuscitation.⁶⁸ In pigs, agonal respiration occurs during the first 2 min following induction of ventricular fibrillation. This declines over time, to 42% at 3 min and 17% at 7 min. Human studies have also documented that agonal ventilation is common in the early stage of cardiac arrest, occurring in as many as 40% patients suffering an out-of-hospital arrest.⁶⁹ Furthermore, in a recent study by Bobrow et al gasping was associated with increased survival.⁷⁰ According to Deakin et al, passive tidal volumes were significantly less than the patient's estimated deadspace, while CO₂ minute volume, an estimate of actual gas exchange, was approximately 10% of the normal range.⁷¹ A mechanism of ventilation similar to those described in high frequency ventilation may be occurring due to the relatively high respiratory frequency. These mechanisms include direct bulk flow, longitudinal dispersion, asymmetric velocity profiles, and molecular diffusion.⁷² Mechanical agitation from external chest compression may also affect mixing of respiratory gases.

Another reason for the efficacy of cardiac-only resuscitation could be that mouth-to-mouth ventilation (MTMV) has several potential disadvantages. These disadvantages include gastric insufflations and, importantly, less cycle time spent on effective compressions.^{18-19,38,73} According to previous animal studies, MTMV can lead to substantial decreases in the aortic diastolic and coronary perfusion pressures.^{40,56} Furthermore, in the study by Kern et al, it took from

3 up to 7 compressions to restore the same pressure achieved just prior to giving the intermittent rescue breaths.⁵² According to the authors, in the group that received conventional CPR, the longer pause between compressions may have resulted in greater "runoff" of blood from the aorta, thereby decreasing the aortic volume and pressure. Another problem associated with MTMV is the composition of the air exhaled by the rescuers. Wenzel et al showed that the rescuers exhaled a mean CO₂ concentration of 3.5% to 4.1% and a mean O₂ concentration of 16.6% to 17.8%.⁷⁴ The same research group in a different study showed that animals ventilated with 95% O₂ and 5% CO₂, a mixture with a higher O₂ and an equal CO₂ concentration to the one mentioned above, fared as poorly as animals given no ventilation during CPR.⁷⁵

International consensus on cardiac-only resuscitation

Although evidence continues to mount from many sources, supporting the use of CO-CPR, to date the scientific data are not powerful enough to warrant any substantial change in the current guidelines. The ERC, according to its online announcement in March 2008, does not intend to change or supplement the current resuscitation guidelines. It emphasizes that only those lay rescuers who are unwilling or unable to give mouth-to-mouth ventilation should provide CPR solely by uninterrupted chest compressions until professional help arrives. In contrast, the AHA, despite agreeing with the ERC statements on the strength of the current evidence regarding CO-CPR, in an effort to increase the unacceptably low rate of bystander CPR in the USA published a science advisory⁶⁸ promoting a call to action for bystanders who are not trained or insufficiently trained in CPR and witness an adult out-of-hospital sudden collapse that is probably of cardiac origin. These bystanders should provide chest compression without ventilation. Bystanders who have been trained and are thus confident with CPR should decide between conventional CPR (chest compression plus ventilation at a ratio of 30:2) and chest compression alone. Nonetheless, it must be noted that, this "call to action" for bystanders does not apply to some patient groups, such as those with long untreated arrest intervals, pediatric victims, and primary respiratory events (drowning, trauma, airway obstruction and acute respiratory diseases). The distinction between cardiac and respiratory arrest has raised some concerns about the possibility that bystanders may be further confused and discouraged

from attempting any type of resuscitation. Nevertheless, no hard evidence for this has been seen so far.⁷⁶

Conclusions

It is clear that any bystander resuscitation is better than no resuscitation at all and that unnecessary chest compression interruptions should be minimized. After taking into account the American committee's appraisal and the results of the current published trials, we believe that CO-CPR may be applicable in those cases where a cardiac etiology is likely, especially if it could increase the rate of bystander resuscitation. In Greece, considering the low prevalence of current training and the lack of knowledge of basic aspects of CPR practice, the introduction of a widespread simplified CPR training program could prove quite helpful.⁷⁷ However, in view of the lack of definitive evidence from clinical trials, no firm suggestions can be made concerning the use of CO-CPR, while the effect of this simplified method on bystander CPR rates remains to be proven. Future adequately powered randomized clinical trials will help to further elucidate these issues.

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