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This new approach, known as CCR, significantly modifies standard CPR to provide more consistent myocardial and central nervous system perfusion during cardiac arrest.

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Assumptions of how quickly two mouth-to-mouth breaths could be delivered by lay persons were found to be erroneous by Assar and colleagues in a large lay person CPR training study.11 In this study of nearly 500 lay person single rescuers, the average time needed to deliver two mouth-to-mouth breaths was 16 seconds, not the four seconds recommended in the CPR guidelines. This means that during a single lay person’s attempt at resuscitation, no chest compressions are being performed for a substantial amount of time—up to 50% of the resuscitation time in some cases. Such lengthy periods without chest compressions result in marked compromise in blood flow to the heart and brain12 and, ultimately, a decrease in survival.3 The use of CCCs avoids these interruptions and provides better hemodynamic support, resulting in better outcomes.

The second component of CCR is a new advanced cardiac life-support (ACLS) treatment algorithm for emergency medical services (EMS) personnel.2–4,13 This algorithm emphasizes uninterrupted chest compressions regardless of other ongoing assignments as part of the

Abstract
This article reviews research showing that cardiopulmonary resuscitation (CPR) as it has been practiced and as it is currently taught and advocated is far from optimal. Cardiocerebral resuscitation (CCR) is a new approach to patients with out-of-hospital cardiac arrest that has been shown to improve rates of neurologically intact survival, aided by emergency medical services (EMS) systems. CCR comprises three major components: continuous chest compressions (CCCs) without mouth-to-mouth ventilation, which can be performed by bystanders who witness cardiac arrests or by the first members of the EMS team to reach the scene; a new advanced cardiac life support algorithm; and the establishment of cardiac arrest centers that can provide optimal care, including urgent cardiac catheterization, controlled mild therapeutic hypothermia, and standardized supportive care for patients in comas after resuscitation from cardiac arrest.

Keywords
Cardiocerebral resuscitation, continuous chest compressions, hands-only cardiopulmonary resuscitation, continuous oxygen insufflation

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The second component of CCR is a new advanced cardiac life-support (ACLS) treatment algorithm for emergency medical services (EMS) personnel.2–4,13 This algorithm emphasizes uninterrupted chest compressions regardless of other ongoing assignments as part of the
Cardiocerebral Resuscitation

Figure 1: Simplified Algorithm for Cardiocerebral Resuscitation

1st EMS arrival
- 200 chest compressions
- Apply defibrillator pads
- Passive insufflation with 100% O₂
- Begin IV or IO
- 1mg epinephrine every 3–5 minutes
- ** If adequate bystander chest compressions are provided, perform immediate rhythm analysis and shock if indicated
- ** Once these tasks are completed, relieve first EMS and perform chest compressions
- Consider endotracheal intubation

2nd EMS arrival
- 200 chest compressions
- ** Once these tasks are completed, relieve first EMS and perform chest compressions
- Single shock if indicated followed immediately by chest compressions at 100/minute without pulse check or rhythm analysis

Begin with 200 uninterrupted chest compressions. The second rescuer can apply both defibrillator pads and continuous oxygen insufflation, placing an oral/pharyngeal airway and then a non-rebreather mask with high-flow oxygen (10–15 L/minute) on the patient’s face. After the initial 200 chest compressions, a rhythm analysis is performed. Shockable rhythms are treated with a single shock; then 200 more uninterrupted chest compressions are immediately administered (without precedent rhythm analysis). During the first or second cycle of 200 compressions, either an intravenous or an intraosseous line can be secured by the second or third rescuer. Once an effective line is secured, epinephrine 1mg should be administered. After finishing the second 200 chest compressions, an additional rhythm analysis is performed. If the patient responds with spontaneous movement during a chest compression cycle, cease compressions and evaluate both rhythm and vital signs. If a shockable rhythm is detected, apply another single defibrillation shock; then an additional 200 uninterrupted chest compressions (third cycle of compressions). If the patient remains unresuscitated, consider endotracheal intubation. EMS = emergency medical services; IO = intraosseus; IV = intravenous.

Cardiocerebral Resuscitation

Cardiocerebral Resuscitation Improves Survival

Dr Kellum and colleagues instituted CCR in Rock and Walworth counties in Wisconsin in 2004. Their historical control period of the preceding three years, when the 2000 guidelines were operative, produced a neurologically intact survival rate at hospital discharge of 15%. During the first three years following the introduction of CCR, the neurologically intact survival rate was 40% (including one patient who suffered from hypothermia). Thus, CCR appeared to be of great benefit in a rural setting.

Bobrow and associates instituted CCR (reported as ‘minimally interrupted cardiac resuscitation’) in metropolitan areas in Arizona in 2004 and found a >300% improvement (from 5 to 18%) in survival to hospital discharge in the subgroup of patients with witnessed cardiac arrest and a shockable rhythm on arrival of the EMS firefighters/paramedics.

Cardiocerebral Resuscitation

Cardiocerebral Resuscitation Leads to More Cardiopulmonary Resuscitation Performed by Law Enforcement Officer Bystanders

The CCR protocol recommends chest-compression-only CPR for all bystanders, including untrained lay persons, CPR-certified individuals, and even those with a duty to respond (police, firefighters, and medical personnel). It was anticipated that this recommendation would increase the incidence of CPR being performed by lay person bystanders. Dr Kellum observed that in Rock and Walworth counties, Wisconsin, following the introduction of CCC CPR, the incidence of CPR performed by law enforcement officer bystanders increased (personal communication). Knowing that they would not be required to perform mouth-to-mouth ventilations, law officers with or without automated external defibrillators (AEDs) appeared more likely to initiate bystander rescue effort. For example, early endotracheal intubation is discouraged to prevent interruption of chest compressions.

In the new algorithm, on arrival EMS providers administer 200 chest compressions prior to obtaining a rhythm analysis; if ventricular fibrillation (VF) or ventricular tachycardia (VT) is present, a single defibrillation shock is provided. Immediately after the single defibrillation shock, an additional 200 chest compressions are administered before another rhythm analysis is performed. Three cycles of 200 compressions, then another rhythm analysis are completed before endotracheal intubation is considered.

During the initial implementation of CCR in Tucson, endotracheal intubation was delayed until at least six minutes of CCCs had been provided. Instead of intubation, the CCR protocol advocated bag–valve–mask ventilation. The current algorithm for CCR advocates passive oxygen insufflation rather than positive-pressure bag–valve–mask as the initial form of airway management. This alternative to endotracheal intubation was originally initiated in Rock and Walworth counties in Wisconsin in 2004. A hybrid approach was used in selected metropolitan cities of Arizona in 2005, and initially in 46 fire departments throughout Arizona between 2006 and 2007. This algorithm also delayed endotracheal intubation but allowed either bag–valve–mask ventilation or passive oxygen insufflation. In each, survival in the subset of patients with out-of-hospital cardiac arrest who had the greatest chance of survival, e.g. those with a witnessed cardiac arrest and a shockable rhythm on EMS arrival, was significantly improved. In the current CCR protocol, passive oxygen insufflation is preferred over bag–valve–mask-assisted ventilation, with a recent report showing improved survival when oxygen insufflation is utilized.

A third component has recently been added to CCR: aggressive post-resuscitation care. This includes the use of mild therapeutic hypothermia and emergent cardiac catheterization with percutaneous coronary intervention when appropriate for all resuscitated victims of out-of-hospital cardiac arrest. Randomized trials have shown the value of mild hypothermia in improving outcome and neurologic function post-resuscitation. Recent data showed that early coronary angiography and percutaneous coronary intervention also improve outcomes among those successfully resuscitated from cardiac arrest. Analysis of nearly 1,000 patients treated this way post-resuscitation suggests that a 65% survival rate can be achieved, with 80% of such survivors being neurologically intact.
CPR in patients with cardiac arrest. This phenomenon has now been documented in Arizona as well. Bobrow and Clark analyzed the incidence of bystander CPR performed by law enforcement personnel during three time periods: before 2006, during 2006, and during 2007. The incidence of chest compressions plus mouth-to-mouth ventilations by law enforcement bystanders was relatively constant at 9, 10, and 13%, respectively. By contrast, the incidence of chest-compression-only CPR during these same three periods increased with the advent of CCR, from 27 to 64% and then to 68%, respectively.

CCR advocates either immediate or delayed defibrillation, based on the three-phase time-sensitive model of VF.20 Accordingly, immediate defibrillation, if appropriate, is recommended during the electrical phase of untreated VF.4,4 However, EMS personnel in most cities typically arrive after the electrical phase, in the circulatory phase of VF arrest.2 During the circulatory phase of VF arrest (after four or five minutes of untreated VF), the fibrillating myocardium has used up much of its energy stores, and chest compressions that perfuse the heart are advocated not only prior to but also immediately after a single defibrillator shock.11 The CCR protocol advocates 200 chest compressions (100 per minute) without assisted ventilation prior to a single defibrillation shock.14,15 Equally important in the CCR protocol is the provision of 200 chest compressions initiated immediately after a single shock without rhythm analysis or pulse check.14,16

Since our group and others found that, during the circulatory phase of VF arrest, any interruption or delay in chest compressions was deleterious, endotracheal intubation (which always interrupts chest compressions to some degree) is initially prohibited by CCR.4,6–8,13,14 To avoid the common mistake of EMS providers hyperventilating during cardiac arrest,22 the current CCR approach to ventilation is passive oxygen insufflation. This consists of first inserting an oral pharyngeal airway then placing a non-rebreather mask with a high flow (10–15 l/min) of oxygen.11,12 Intubation and positive pressure ventilation is indicated after three cycles of chest compressions (200 compressions each) without return of spontaneous circulation, or once return of spontaneous circulation is achieved if the patient does not have adequate respiratory effort. Once circulation is restored, endotracheal intubation can be performed for airway protection prior to hospital transport.

CCR is not recommended for individuals with respiratory arrest. These individuals require early ventilatory assistance including early intubation. CCR is indicated in individuals under 18 years of age if the arrest is presumed to be of cardiac origin, for example a young person who has commotio cordis (cardiac arrest secondary to a blow to the precordium) has a cardiac and not a respiratory arrest. Approximately 10% of patients under 18 years of age who have in-hospital cardiac arrest have VF or VT as their initial arrhythmia.23 Therefore, the recommendation for CCCs as part of CCR is not age-dependent, but rather applies to all individuals with a presumed cardiac arrest (i.e. persons unresponsive after a sudden unexpected collapse who are not breathing normally).

The recently added third component of CCR, namely aggressive post-resuscitation care, has been shown by Kjetil et al. to double survival compared with historical rates.24 Merely organizing a formal approach to post-resuscitation care that includes therapeutic mild hypothermia and early coronary angiography improved the rate of hospital discharge with favorable neurological outcome from 26 to 56% (p<0.001).25 The CCR protocol now advocates therapeutic hypothermia combined with emergent cardiac catheterization and possibly percutaneous coronary intervention for all successfully resuscitated victims of cardiac arrest. Through the Arizona Department of Health Services Bureau of Emergency Medical Services and Trauma Systems, Bobrow and associates have established ‘cardiac arrest center’ hospitals in Arizona, much like the current ‘trauma center’ designations. These hospitals must be able and willing to provide therapeutic hypothermia and urgent cardiac catheterization for resuscitated victims of out-of-hospital cardiac arrest.

Role of Cardiocerebral Resuscitation in Unwitnessed, Prolonged, or Asystolic Cardiac Arrest

There has been concern that CCR, with its emphasis on chest compressions without initial assisted positive pressure ventilation, might adversely affect patients with unwitnessed VF or, in particular, non-VF cardiac arrest rhythms such as asystole or pulseless electrical activity (PEA). The survival to hospital discharge data from the metropolitan Phoenix area show an increase from 1.8% (four of 218) before the CCR era to 5.4% (36 of 668) after instituting CCR (odds ratio [OR] 3, range 1.1–8.6). Further analysis of this population of non-selected out-of-hospital cardiac arrest victims showed that two of the four survivors in the pre-CCR period had unwitnessed VF or non-VF, while 13 of the 36 survivors had similar rhythms in the post-CCR study period. This translates into a survival rate for the unwitnessed VF or non-VF of 0.9% (two of 218) in the pre-CCR era and 1.9% (13 of 668) post-CCR. The χ² is 1.045, indicating an insignificant p-value of 0.3. Hence, no significant difference in outcome was found, although survival to discharge was doubled (not decreased) in the post-CCR era.2 These data suggest that CCR is not detrimental in patients whose cardiac arrest is not from a witnessed VF cardiac arrest.

Conclusions

CCR has increased bystander participation in resuscitation efforts, resulting in more blood flow being provided to the heart and brain during the crucial early minutes of cardiac arrest, and has improved long-term survival rates in a number of communities, both urban and rural. Now is the time for other communities to re-examine their own outcomes with cardiac arrest and consider joining those cities and communities that have doubled and even tripled survival rates after out-of-hospital cardiac arrest.
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