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Cardiocerebral resuscitation: The optimal approach to cardiac arrest

Cardiac arrest highlights one of the critical interactions between the heart and the brain, and it remains a leading cause of death in the United States, Canada, and Europe. This summit provides an opportunity to advocate cardiocerebral resuscitation as an alternative to traditional cardiopulmonary respiration (CPR) for out-of-hospital cardiac arrest. Because cardiocerebral resuscitation results in improved survival and cerebral function in patients with witnessed cardiac arrest with a shockable rhythm (the subgroup with the greatest chance of survival), it should replace CPR for out-of-hospital cardiac arrest.[1–4] CPR should be reserved for respiratory arrest.

This discussion will explore the rationale for abandoning traditional CPR for out-of-hospital cardiac arrest and explain what cardiocerebral resuscitation is and why it should replace CPR in this setting.

WHY DOES CPR FOR CARDIAC ARREST NEED TO BE REPLACED?

Past, present CPR guidelines flawed

Despite the development and periodic updating of guidelines for CPR and emergency cardiovascular care from the American Heart Association (AHA)[5] and the International Liaison Committee on Resuscitation (ILCOR),[6] survival rates for victims of out-of-hospital cardiac arrest are dismal and have remained essentially unchanged for decades.[7,8] An important reason for these continued poor outcomes is that both sets of guidelines, despite being updated in 2005, recommend an approach to out-of-hospital cardiac arrest that is far from optimal.

Different approaches required for cardiac and respiratory arrest

Specifically, both the AHA and ILCOR guidelines continue to advocate CPR for two different pathophysiologic conditions: primary cardiac arrest and cardiac arrest secondary to respiratory failure.[5,6] Thus, both sets of guidelines recommend mouth-to-mouth ventilations for all cardiac arrests. This approach has three major drawbacks:

- Most bystanders to a person who unexpectedly collapses are willing to activate emergency medical services (EMS) but are not willing to initiate rescue efforts because they do not want to perform mouth-to-mouth assisted ventilation.[9] Bystanders are more willing to perform chest-compression-only resuscitation for a person who unexpectedly collapses, an approach that all agree is dramatically better than doing nothing. (As it turns out, chest compression alone for cardiac arrest is as good as or better than the guideline-recommended approach of interrupting chest compressions for mouth-to-mouth ventilations; see below.)
- Interrupting chest compressions for ventilation during cardiac arrest decreases survival.[10,11]
- Positive pressure ventilation during CPR for cardiac arrest increases intrathoracic pressures, which decreases venous return to the thorax and subsequent perfusion of the heart and the brain.[12,13]

Any delay in chest compressions can be deleterious

The importance of uninterrupted chest compressions to cerebral function was forcefully brought home to me and my colleagues as we listened to a recording of a woman trying to resuscitate her husband. She asked, "Why is it that every time I press on his chest he opens his eyes, and every time I stop to breathe for him he goes back to sleep?"[3] Brain perfusion during resuscitation efforts for cardiac arrest is so marginal that any interruption in chest compressions, even for ventilations, has the potential of being deleterious.

CARDIOCEREBRAL RESUSCITATION ELIMINATES VENTILATION

In contrast to CPR, cardiocerebral resuscitation eliminates mouth-to-mouth ventilation for bystander-initiated resuscitation efforts, dramatically decreases the

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role of positive pressure ventilation by EMS responders, and emphasizes chest compressions prior to and immediately after a single shock for cardiac arrests not witnessed by EMS personnel.[2,3,14–18]

The evidence base

Bystander-initiated chest-compression-only resuscitation for witnessed unexpected collapse in adults (cardiac arrest) is based on extensive CPR research in swine. The University of Arizona Sarver Heart Center CPR Research Group found that chest-compression-only resuscitation for cardiac arrest in swine not only was dramatically better than no CPR but also was associated with dramatically better survival than CPR consisting of two ventilations before each 15 chest compressions,[19] the practice recommended in 2000 consensus guidelines from the AHA and ILCOR.[20]

In a human study, investigators from Japan found that among witnessed victims of out-of-hospital cardiac arrest who had a shockable rhythm upon the arrival of EMS personnel, chest-compression-only resuscitation resulted in better survival than did chest compressions plus mouth-to-mouth ventilation.[21]

Why guidelines slight chest compression alone

Unfortunately, the findings of these Japanese investigators were published only in abstract form at the time the 2005 AHA guidelines were considered. Therefore, chest-compression-only resuscitation by bystanders is recommended in these guidelines only "if the individual is unwilling or unable" to perform chest compression and mouth-to-mouth ventilation.[5,20]

Another putative reason the guidelines continue to recommend both ventilation and chest compression is that patients with respiratory arrest do need ventilation and might not receive ventilation if chest-compression-only resuscitation were advocated. However, in Tucson, Arizona, where I practice, there is approximately one death from drowning for every 100 cardiac arrests. This shows that any desire to avoid "complicating the message" about resuscitation for the sake of respiratory arrest victims is actually jeopardizing a vastly larger group of cardiac arrest victims.

What the public should be taught about resuscitation

The message that needs to be promulgated is twofold but nevertheless simple: cardiocerebral resuscitation is for cardiac arrest, while CPR with ventilation is recommended for respiratory arrest. The lay public should be taught that an unexpected collapse in an adult is, in all likelihood, a cardiac arrest, to be differentiated from obvious respiratory arrest, such as choking or drowning, where assisted ventilations may be appropriate.

CORONARY PERFUSION PRESSURE IS ESSENTIAL DURING PROLONGED CARDIAC ARREST

In the absence of early defibrillation, survival beyond the first 5 minutes of ventricular fibrillation (VF) arrest is predominantly dependent on adequate coronary and cerebral perfusion pressures, both of which are generated by chest compressions. It is well established that in the absence of early defibrillation or bystander-initiated resuscitation efforts, survival is rare.

The Sarver Heart Center CPR Research Group has now published six experimental studies that included a total of 169 swine, all of which showed that with prolonged cardiac arrest due to VF, survival is the same with chest-compression-only resuscitation as with ideal CPR—ie, CPR in which chest compressions were interrupted for only 4 seconds for respiration.[3] After the 2000 AHA/ILCOR guidelines were published, Assar et al[22] found that when single lay rescuers perform CPR, they interrupt chest compressions for an average of 16 seconds to deliver the two recommended mouth-to-mouth ventilations. Subsequently, our CPR Research Group compared survival in a realistic porcine model of out-of-hospital cardiac arrest using 16-second interruptions for the two recommended ventilations between each 15 chest compressions, and we found that 24-hour survival was only 13% in this group, compared with greater than 70% survival in all of our studies of chest-compression-only resuscitation prior to the simulated arrival of EMS personnel.[19]

The decades-old recommendation of two ventilations before each 15 chest compressions has recently been acknowledged not to be optimal, as this ratio was changed from 2:15 to 2:30 in the 2005 AHA guidelines[5] to increase the recommended number of chest compressions. However, this change did not address the major problem, which is bystanders' reluctance to initiate resuscitation if ventilation is involved, regardless of the ventilations-to-compressions ratio. The greatest impediment to the initiation of bystander resuscitation is the public's aversion to and/or the complicated nature of performing mouth-to-mouth resuscitation.

WHAT IS THE ROLE OF GASPING OR AGONAL RESPIRATIONS?

When a person collapses with VF, or if VF is induced in an animal model, gasping is present in a significant number of individuals and animals. This abnormal breathing, which varies in duration, can be either fortunate or unfortunate. When chest compressions are promptly initiated, gasping is fortunate in that the subject is likely to continue to gasp and provide self-ventilation (negative intrathoracic pressure). However, gasping also may be unfortunate in that most laypersons interpret it as an indication that the subject is still breathing, causing them not to initiate bystander resuscitation or call for EMS personnel as soon as they should. Education will be essential to ensure prompt initiation of bystander chest compressions in patients who gasp with cardiac arrest, as well as to ensure that chest compressions are not stopped because of continued gasping.

IMPLEMENTING CARDIOCEREBRAL RESUSCITATION INTO EMS PROTOCOLS

The Sarver Heart Center CPR Research Group has been advocating chest-compression-only resuscitation by bystanders since the early 1990s. In our programs, laypersons are taught to "be a lifesaver." They are instructed to call 911 as soon as possible and then to begin chest compressions alone. If an automated external defibrillator (AED) is available, they should obtain it and follow its directions. Rescue breathing is not recommended. The technique for chest compressions is ideally taught with emphasis on a metronome-guided rate of 100 per minute. Additionally, full chest recoil after each compression is specifically emphasized.

Guidance from the three phases of cardiac arrest

Adoption of the cardiocerebral resuscitation technique will prompt some changes in EMS protocols; these are best understood in the context of the three phases of cardiac arrest due to VF. The three-phase time-dependent conception of cardiac arrest due to VF was articulated by Weisfeldt and Becker.[23]

The electrical phase is the first phase, lasting about 5 minutes. The most important intervention during this phase is defibrillation. This is why the availability of AEDs and programs to encourage their use have saved lives in a wide variety of settings, including airplanes, airports, casinos, and the community.

The circulatory phase is next. It varies in duration but runs approximately from minute 5 to minute 15 of VF arrest. During this time, generation of adequate cerebral and coronary perfusion pressure before and after defibrillation is critical to neurologically normal survival. Ironically, if an AED is the first intervention applied during this phase, the subject is much less likely to survive.[24,25] If preshock chest compressions are not provided, defibrillation during the circulatory phase almost always results in a pulseless rhythm, asystole, or pulseless electrical activity. The previous stacked-shock protocol for the use of AEDs resulted in prolonged interruption of essential chest compressions, not only for rhythm analysis before shocks but also for rhythm analysis after shocks during this circulatory phase of cardiac arrest.[24,26] Successful resuscitation from these pulseless rhythms requires not only preshock chest compressions but also prompt, effective postshock resumption of chest compressions.[3,4]

The metabolic phase occurs late (sometime after 15 minutes) in cardiac arrest due to VF. This is when resuscitative efforts are least successful and is the phase for which new innovative concepts are needed.

Changes in cardiac life-support protocols

One reason why survival of out-of-hospital cardiac arrest has been so poor is that paramedics, who almost always arrive after the electrical phase of cardiac arrest due to VF, spend only half their time doing chest compressions.[27,28] Interruptions are frequent because EMS personnel have been following existing guidelines. One of the more unfortunate recommendations of the old guidelines is the emphasis on stacked defibrillation,[20] which results in a lack of chest compressions during prolonged and repeated analysis by AEDs during the circulatory phase of cardiac arrest due to VF—delays that have proved to be lethal.[25]

Similarly problematic has been the use of endotracheal intubation by EMS rescuers. Not only does the placement of endotracheal tubes interrupt chest compressions, but intubation also causes adverse effects related to positive pressure ventilation and frequent hyperventilation.[3]

In contrast, cardiocerebral resuscitation discourages endotracheal intubation during the electrical and circulatory phases of cardiac arrest due to VF.[2–4] Defibrillator pad electrodes are applied and the patient is given 200 chest compressions and then a single defibrillation shock that is immediately followed by 200 more chest compressions before the rhythm and pulse are analyzed.[4]

These additional 200 chest compressions applied after the shock but before rhythm and pulse analysis represent another important aspect of cardiocerebral resuscitation.[3,4] This practice is based on our swine model of out-of-hospital cardiac arrest, in which we observed that after prolonged VF an effective shock rarely (almost never) produced a perfusion rhythm.[2] Therefore, chest compressions were immediately initiated until an arterial pressure was established.

A new approach to oxygenation

In our later versions of cardiocerebral resuscitation, a new approach to oxygenation is recommended.[4] Aufderheide has documented that positive pressure ventilation during VF arrest is detrimental, concluding that "there is an inversely proportional relationship between mean intrathoracic pressure, coronary perfusion pressure, and survival from cardiac arrest."[12] Adverse effects of positive pressure ventilation include an increase in intrathoracic pressure as well as the inability to develop a negative intrathoracic pressure during the release phase of chest compression.[12] Positive pressure ventilation inhibits venous return to the thorax and right heart, resulting in decreased coronary and cerebral pressures. Additionally, hyperventilation and increased intrathoracic pressure have adverse effects on intracranial pressure and cerebral perfusion pressure. These effects are compounded by the fact that ventilation rates by physicians and paramedic rescuers are often much faster than the rate recommended by the guidelines,[20] even after extensive retraining.[3,13] During cardiac arrest, faster ventilation rates increase the mean intrathoracic pressure and further impede forward blood flow.

Accordingly, cardiocerebral resuscitation recommends opening the airway with an oropharyngeal device, placement of a nonrebreather mask, and administration of high-flow (about 10 L/min) oxygen.[4]

INITIAL DATA ON CARDIOCEREBRAL RESUSCITATION IN HUMANS

Data comparing cardiocerebral resuscitation with standard CPR in humans are beginning to emerge. Kellum and colleagues reported their initial experience after instituting the current version of cardiocerebral resuscitation by EMS personnel in two rural Wisconsin counties in 2004.[4] Among the first 33 patients with witnessed out-of-hospital cardiac arrest and a shockable rhythm treated after institution of cardiocerebral resuscitation, neurologically normal survival was achieved in 48% of patients. This represents a significant improvement from the 15% rate achieved during the previous 3 years when standard CPR (according to AHA guidelines) was followed.

CONCLUSIONS

Uninterrupted perfusion of the heart and brain prior to defibrillation during prolonged cardiac arrest is essential to neurologically normal survival. It is our conviction that the widespread implementation of cardiocerebral resuscitation for cardiac arrest will dramatically improve survival.

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