EDITORIAL COMMENT

Cardiocerebral resuscitation should replace cardiopulmonary resuscitation for out-of-hospital cardiac arrest

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Current Opinion in Critical Care 2006, 12:189–192

Abbreviations

AED automatic external defibrillator
CPR cardiopulmonary resuscitation

1070-5295

Introduction

The articles in this issue of *Current Opinion in Critical Care* are essential reading for all those interested in cardiopulmonary resuscitation (CPR). This editorial will expand on the data presented to support the conviction that cardiocerebral resuscitation should replace CPR for out-of-hospital cardiac arrest [1,2].

Why does CPR need to be replaced? Sudden cardiac death is a major health problem in industrialized nations and the present approach to out-of-hospital cardiac arrest is far from optimal. In spite of the development, periodic updates, and promulgation of guidelines for CPR, survival of victims of out-of-hospital cardiac arrest remains dismal.

One contributor to this paradox is the fact that CPR has been and continues to be advocated for two entirely different pathophysiologic conditions; cardiac arrest and respiratory arrest. The approach to these two types of arrest should be different. Recommendations that are essential for one may not be effective for the other. The putative reason for a single approach to these entirely different pathophysiologic conditions is that the public cannot tell the difference between a cardiac arrest and a respiratory arrest. We think that the public can be taught the difference between individuals with sudden, unexpected collapse (in all likelihood, cardiac arrest) and victims of drowning, drug overdose who just stop breathing, and individuals with upper respiratory obstruction (in all likelihood, respiratory arrest).

Changes to the current guidelines are inevitable

Fortunately, there is a new era of resuscitation approaching as recent studies in humans have confirmed experimental findings supporting cardiocerebral resuscitation for witnessed out-of-hospital cardiac arrest. Unfortunately, these finding were not considered by the writers of the 2005 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, nor by the International Liaison Committee on Resuscitation [3,4]. Are these new resuscitation guidelines optimal? As Douglas Chamberlain points out in his insightful article in this issue (pp. 193–197), the answer 'might strictly be answered in the single word "no".' He then writes that this no, 'should not be taken as any adverse criticism either of the process or of the conclusions that were reached.' As so many lives are at stake, I, however, will not be as diplomatic as my friend and colleague and conclude that these guidelines were outdated even as they were written. As a result of this many in the world are not following and will not follow them.

This editorial will outline and reference some of the evidence that was known at the time of the writing of the 2005 guidelines, but was not accepted because the peer-reviewed data were from animal experiments and the information in humans was present only in abstract form. Even though we are all scientists, our interpretation of evidence is filtered through the gauze of our own biases, including my own. I am biased toward the findings from our experimental laboratory, as over the past two decades data from our CPR research laboratory at the University of Arizona College of Medicine have been the basis for previous positive guideline changes.

Early defibrillation has long been known to improve survival. Unfortunately the promise of the automatic external defibrillators (AEDs) has not been fulfilled as they are rarely available in the early or electrical phase of ventricular fibrillation [5].

Major changes are needed in bystander rescuer techniques

In the absence of early defibrillation, survival beyond the electrical phase of subjects in cardiac arrest due to ventricular fibrillation is predominantly dependent upon coronary and cerebral perfusion pressures, both generated by chest compressions [6,7]. The hemodynamics of cardiac arrest are reviewed in the excellent article by Andreka and Frenneaux in this issue of *Current Opinion in Critical Care* (pp. 198–203). It is well known that in the absence of bystander-initiated resuscitation efforts, survival is rare. Yet the greatest impediment to the initiation of bystander resuscitation efforts is the aversion to or the complicated nature of mouth-to-mouth resuscitation. This is the reason that our group has been advocating chest-compression-alone bystander resuscitation since the early 1990s [8].

Since then we have published six studies that contained data from 169 swine showing that with prolonged cardiac arrest due to ventricular fibrillation, survival is the same with chest-compression-alone resuscitation as with ideal CPR, when chest compressions are interrupted for only 4 s for respiration. After the 2000 American Heart Association guidelines were published, Assar *et al.* [9] showed that a single lay rescuer interrupts chest compressions for an average of 16 s to deliver the two recommended mouth-to-mouth ventilations [9]. Our CPR research group then compared survival in a realistic porcine model of out-of-hospital cardiac arrest with the 16 s interruptions for the two recommended ventilations between each 15 chest compressions and found that 24 h survival was only 13% in this group, compared to the over 70% survival in all of our studies of chest-compression-alone CPR prior to the simulated arrival of emergency medical services [10].

The prevalence of bystander-initiated CPR varies but averages somewhere between 20 and 30%. Surveys indicate that prevalence could be markedly increased if bystander chest-compression-alone CPR was advocated for individuals with witnessed unexpected sudden collapse. This has not been recommended, however, 'unless one is unable or unwilling to do mouth-to-mouth rescue breathing,' and certainly has not been taught. As a result of our research findings, chest-compression-alone 'CPR' has been advocated since November 2003 in Tucson, Arizona [1,2,11].

There are data in humans to support chest compression alone for bystander resuscitation, but at the time the guidelines were being written these data were only in abstract form. Although this abstract was presented at the American Heart Association Scientific Sessions in 2005 and was awarded the distinction of the best abstract in CPR, the data were not considered by the writers of the guidelines, as they were in an abstract. However, their findings in humans confirm our experimental findings.

The investigators from the Kanto area of Japan performed a survey of survivors in a study designated SOS-KANTO [12]. They reported on 9592 out-of-hospital arrests. Of these, 4241 were witnessed. No bystander CPR was provided by 2917 cases (69%) and bystander CPR was provided in 1324 cases (31%). The type of bystander CPR was documented in 1151 cases. Of these, 712 victims (62%) received chest compression plus mouth-to-mouth ventilation and 439 victims (38%) received chest compression alone. Neurologically normal survival at 30 days was greater in those with witnessed arrest with ventricular fibrillation or pulseless ventricular tachycardia as the first cardiac arrhythmia. Neurologically normal survival in this group at 30 days was 8.2% in those who did not receive bystander CPR, 11.2% in those who received chest compression plus mouth-to-mouth resuscitation, and 19.4% for those who received chest compression alone ($P = 0.05$) [12]. The authors concluded that 'chest-compression-alone CPR may be the preferred approach to resuscitation for out-of-hospital cardiac arrest in adults.'

I predict that one of the greatest paradoxes of our time will be the reluctance of the organized medical community to acknowledge the obvious: the lack of bystander-initiated CPR because of the public's reluctance to perform mouth-to-mouth rescue breathing. It is indeed a paradox that a technique that organizations have here to fore not spent a cent advocating nor a minute teaching is at least as good and may be significantly better than the one that they have spent millions of dollars and millions of hours advocating and teaching.

The recommended 2:15 ventilation/chest compression ratio of the past decade is not optimal or it would not have been changed in the 2005 guidelines [13]. The change from the recommended 2:15 ventilations to a ratio of 2:30 was made to increase the number of chest compressions [13]. Yet, bystanders who will not perform mouth-to-mouth rescue breathing at the 2:15 ratio are no more likely to perform them at 2:30 or at two ventilations to whatever number of chest compressions one selects.

In our programs, lay persons are taught to 'be a lifesaver – call and pump' [1,2,14] (see http://callandpump.org/assets/Proposal_Current.pdf). They are to call the emergency services as soon as possible and then begin chest compressions alone: that is, pump on the chest. Rescue breathing is not recommended. The technique is ideally taught with emphasis on a metronome-guided rate of 100/min. Additionally, full chest recoil after each compression is specifically emphasized [14]. This approach can be easily and efficiently taught.

What is the role of gasping or agonal respirations?

Another observation is that if a person collapses with ventricular fibrillation, or if ventricular fibrillation is induced in the experimental laboratory, gasping is present in a significant number of individuals and animals (see the excellent review by Mickey Eisenberg in this issue, pp. 204–206). This abnormal breathing lasts for a variable period of time. Gasping is both fortunate and unfortunate. It is fortunate because when chest compressions are initiated promptly the subject is likely to continue to gasp and provide self-ventilation. In fact, in one of their early programs Kouwenhoven, Jude, and Knickerbocker, the fathers of CPR, indicated that assisted ventilations were not necessary during chest compression because the subject gasped (J.R. Jude, personal communication).

However, gasping may be unfortunate as most lay individuals interpret this as an indication that the individual is still breathing, and do not initiate bystander CPR or notify the emergency medical system as soon as they should. Education will be essential to assure prompt initiation of bystander chest compressions in patients who gasp with cardiac arrest, and education will be necessary to ensure that chest compressions are not stopped because of continued gasping.

Major changes are also needed in advanced cardiac life support

Another reason that survival of out-of-hospital cardiac arrest has been so poor is the fact that paramedics, who almost always arrive after the electrical phase of cardiac arrest due to ventricular fibrillation, spend only half of the time doing chest compressions [15,16]. Interruptions were frequent because they were following the guidelines. One of the more unfortunate guidelines was the emphasis on stacked defibrillation. This resulted in the lack of chest compressions during prolonged and repeated analysis by AEDs during the circulatory phase of cardiac arrest due to ventricular fibrillation – delays that proved to be fatal [17].

Another major problem during resuscitation efforts by emergency medical personnel is endotracheal intubation [1]. Endotracheal intubation has adverse effects not only due to the interruptions of chest compressions during placement, but also due to the adverse effects of hyperventilation. Accordingly cardiocerebral resuscitation discourages endotracheal intubation during the electrical and circulatory phases of cardiac arrest due to ventricular fibrillation. Defibrillator pad electrodes are applied and the patient is given 200 chest compressions and a single defibrillation shock that is immediately followed by 200 more chest compressions before the rhythm and pulse are analyzed. The 200 compressions at 100/min (2 min of chest compression before defibrillation during the circulatory phase of ventricular fibrillation arrest) is based on the publications of Cobb *et al.* [18] who showed improved survival with 90 s of chest compression before shock, and Wik *et al.* [19] who showed improved survival with 3 min of chest compression prior to defibrillation. We did not want to cause paramedics to be distracted by having to determine time, so 200 compressions at about 100/min were proposed, equal to about 2 min. This is a compromise between the 90 s in the Cobb *et al.* study and the 3 min in the Wik *et al.* study.

Another of the more important aspects of cardiocerebral resuscitation is that after the shock, 200 more chest compressions are provided before rhythm and pulse analysis [1,2]. This is based on our porcine model of out-of-hospital cardiac arrest. In the experimental laboratory the animal is constantly monitored. We observed that after prolonged ventricular fibrillation an effective shock almost never produced a perfusion rhythm. Therefore chest compressions were immediately initiated until an arterial pressure was established.

A new approach to ventilation by emergency medical services is needed

In our later versions of cardiocerebral resuscitation, even a new approach to ventilation is recommended. As Aufderheide so clearly explained and so scientifically documented in this issue (pp. 207–212), positive pressure ventilation is detrimental. As he stated, 'there is an inversely proportional relationship between mean intrathoracic pressure, coronary perfusion pressure, and survival from cardiac arrest' [20,21]. Adverse effects of positive pressure ventilation include an increase in intrathoracic pressure, and the inability to develop a negative intrathoracic pressure during the release phase of chest compression. Positive pressure ventilation inhibits venous return to the thorax and right heart and thus results in decreased coronary and cerebral pressures. Another aspect of hyperventilation and increased intrathoracic pressure is its adverse effect on intracranial pressure and cerebral perfusion pressure [22,23]. These adverse effects are compounded by the fact that ventilation rates by physicians as well as paramedic rescuers are often much faster than the rate recommended by the guidelines, and unfortunately are still significantly above those recommended even after extensive retraining [20,21]. During cardiac arrest, faster ventilation rates increase the mean intra thoracic pressure and further impede forward blood flow.

Accordingly, cardiocerebral resuscitation recommends opening the airway with an oropharyngeal device, placement of a non-rebreather mask, and the administration of high-flow oxygen (about 10 l/min). We recently completed an experimental study (now in preparation) in a realistic porcine model of out-of-hospital cardiac arrest and found that after 8 min of untreated ventricular fibrillation this approach (continuous oxygen insufflation), during the time it takes to deliver three unsuccessful shocks with an AED, resulted in similar 24 h neurologically normal survival in swine to 12 ventilations/min at 10 ml/kg. The major advantage of this approach (continuous oxygen insufflation) is that it not only prevents the many negative effects of positive pressure ventilation but also prevents the near-inevitable hyperventilation (documented average of 37 ventilations/min during the initial observation of paramedic performance in the field, and 20 ventilations/min after retraining of paramedics), and frees up the second emergency medically trained person to trade off chest compressions, obtain intravenous access, or perform other important tasks. Because the physical exertion of rapid chest-compression-only CPR is tiring, and has been shown even in healthy medical students to deteriorate with time, we recommend changing the individuals doing chest compressions every 100 chest compressions, and ensuring full recoil of the victim's chest after each compression [14].

Initial data in humans

What are the data in humans? Soon after we initiated the cardiocerebral resuscitation protocol in Tucson, Dr Mike Kellum and colleagues from Rock and Walworth counties in Wisconsin spent time with us, returned, and instituted the system there. Compared with the survival during the 3 years when cardiopulmonary guidelines were followed, institution of cardiocerebral resuscitation resulted in a dramatic improvement in neurologically normal survival at hospital discharge [14].

Post-resuscitation care

We can do all that is outlined in this editorial and it may not be enough if post-resuscitation care is not also improved. One aspect of post-resuscitation care is therapeutic hypothermia in appropriate patients. This important aspect of post-resuscitation care is reviewed by the excellent article by Sanders in this issue (pp. 213–217).

Acknowledgement

I wish to gratefully acknowledge the past and continuing research collaboration of my colleagues in the University of Arizona Sarver Heart Center CCR Research Group, including Karl B. Kern, Ron Hilwig, Arthur B. Sanders, Robert Berg, Charles Otto, Melinda Hayes, and Mohammad Gabella. Lani Clark and Ben Bobrow of the Arizona SHARE program are helping to collect data before and after they institute cardiocerebral resuscitation statewide in Arizona. Dr Mike Kellum and his colleagues have established cardiocerebral resuscitation in Rock and Walworth counties of Wisconsin and provided data indicating its effectiveness. The men and women of the Fire Department and EMS systems in Tucson are also gratefully acknowledged.

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