STATE-OF-THE-ART PAPER

Alternative Approach to Improving Survival of Patients With Out-of-Hospital Primary Cardiac Arrest

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Out-of-hospital cardiac arrest (OHCA) is a common cause of death. In spite of recurring updates of guidelines, the survival of patients with OHCA was essentially unchanged from the mid 1970s to the mid 2000s, averaging 7.6% for all OHCA and 17.7% for OHCA due to ventricular fibrillation. In the past, changes in one's approach to resuscitation had to await the semi-decennial publications of guidelines. Following approved guidelines (at times based on consensus), survival rates of patients with OHCA were extremely variable, with only a few areas having good results. An alternative approach to improving survival is to use continuous quality improvement (CQI), a process often used to address public health problems. Continuous quality improvement advocates that one obtain baseline data and, if not optimal, make changes and continuously re-evaluate the results. Using CQI, we instituted cardiocerebral resuscitation as an alternative approach and found significant improvement in survival of patients with OHCA. The changes we made to the therapy of patients with primary OHCA, called cardiocerebral resuscitation, were based primarily on extensive experimental laboratory data. Using cardiocerebral resuscitation as a model for CQI, neurologically intact survival of patients with OHCA in ventricular fibrillation improved in 2 rural counties in Wisconsin, from 15% to 39%, and in 60 emergency medical systems in Arizona, to 38%. By advocating chest compression only CPR for bystanders of patients with primary OHCA and encouraging the use of cardiocerebral resuscitation by emergency medical systems, survival of patients with primary cardiac arrest in Arizona increased over a 5-year period from 17.7% to 33.7%. We recommend that all emergency medical systems determine their baseline survival rates of patients with OHCA and a shockable rhythm, and consider implementing the CQI approach if the community does not have a neurologically intact survival rate of at least 30%. (J Am Coll Cardiol 2013;61:113–8) © 2013 by the American College of Cardiology Foundation

Cardiovascular disease is a major public health problem. Unfortunately, the first sign of cardiovascular disease may be the last, as all too often the first sign is sudden death from cardiac arrest (1). In the United States, there are an estimated 300,000 out-of-hospital cardiac arrests (OHCA) each year (1). After the age of 40 years, a male in the United States has a 1 in 8 chance of dying of cardiac arrest (1).

Between 1974 and 2005, 6 national guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care were published (2–7). These guidelines recommend the same treatment of both primary and secondary cardiac arrest. They were based on a consensus of experts after extensive evidence-based medicine reviews of scientific advances. Nevertheless, between 1978 and 2008, the published

survival rate of patients with OHCA in the United States averaged 7.6% and was unchanged over that 30-year period (8). Even when one focuses on OHCAs with ventricular fibrillation (VF), survival averaged 17.7%, unchanged over that 23-year period (Fig. 1) (9). Likewise, in Europe, the survival rate of patients with OHCA due to VF was also unchanged from 1980 to 2004, with an average survival rate of 21% (Fig. 1) (10).

Another problem is the disparate survival rates of patients with OHCA due to VF in different communities. When the Resuscitation Outcomes Consortium analyzed patients with OHCA, treated according to the 2005 guidelines, survival varied fivefold (11). Their median survival of VF OHCA was 22% (Fig. 1), but varied from 7.7% to 39.9% (11). Thus, the assumption that 1 size fits all in addressing a complex, multifaceted public health issue may not be valid.

An alternative approach to address OHCA is continuous quality improvement (CQI), a concept sometimes used to address public health problems (12). Critical to this approach is the measurement of baseline data, implementation of changes, and measurement of outcomes. Indeed, Cobb et al. (13) had previously used this approach. The series of changes we made for the therapy of patients with primary

Abbreviations and Acronyms

CCR = cardiocerebral resuscitation

CO = compression only

CPR = cardiopulmonary resuscitation

DA = dispatch assisted

EMS = emergency medical service

ETI = endotracheal intubation

OHCA = out-of-hospital cardiac arrest

ROSC = return of spontaneous circulation

SHARE = Save Hearts in Arizona Research and Education

VF = ventricular fibrillation

OHCA was termed cardiopulmonary resuscitation (14). This approach was introduced in Tucson, in rural Wisconsin, and then implemented by some of the emergency medical services (EMS) in Arizona (15–19).

This paper reviews the rationale, results, and implications based on the CQI experience of implementing cardiocerebral resuscitation for the treatment of patients with primary OHCA.

Continuous Quality Improvement Approach to Out-of-Hospital Cardiac Arrest

The survival rate of patients with OHCA in VF between 1997 and 1999 in Tucson, Arizona, was poor and unchanged despite instituting each national guideline recommendation update, including the addition of automated external defibrillators (15). That, and the fact that in our experimental laboratory model of OHCA due to VF alternative approaches improved survival, led to our interest in the CQI model.

Cardiocerebral Resuscitation Overview

Cardiocerebral resuscitation initially consisted of the first 2 of the now 3 major components: community, EMS, and hospital (Fig. 2). The survival rates referred to herein do not include the additional improvement that has been seen in Arizona since the institution of the third, or hospital, component (20). Each component involves separate stakeholders, but each is essential to implementation of a coherent system.

Community component of cardiocerebral resuscitation. The community component of cardiocerebral resuscitation (Fig. 2) consists of prompt recognition (check), activation of EMS (call), chest compression only CPR (compress), and the use of an automated external defibrillator if available.

PROMPT RECOGNITION AND EMERGENCY SERVICES ACTIVATION. The treatment of primary and secondary cardiac arrest should be different, and we think the lay public can be taught to recognize the difference between a primary cardiac arrest (an unexpected witnessed—seen or heard—collapse of a person who is not responsive) and a secondary cardiac arrest due to drowning, drug overdose, or respiratory failure. This definition does not mention anything about the presence of arterial pulsations, nor the presence or absence of respirations. Except in newborns, gasping or agonal breathing is a common sign of cardiac arrest (21,22).

EVOLUTION OF COMPRESSION ONLY CPR FOR PATIENTS WITH PRIMARY CARDIAC ARREST. Studies in experimental models from our laboratory in the 1990s demonstrated that survival was better with chest compression only cardiopulmonary resuscitation (CO-CPR) compared to no CPR, and was comparable to the then guidelines for CPR (14). Soon after the 2000 CPR and emergency cardiac care guidelines were published, researchers in the United Kingdom documented that lay persons who were recently certified in basic CPR, when tested on mannequins, interrupted each set of chest compressions for an average of 16 s to deliver the recommended 2 "quick rescue breaths" (23). Thus, when the respiration to compression ratio was 2:15, the patients with OHCA who had lay bystander CPR were receiving chest compressions only half of the time.

Based on consensus, the 2005 guidelines recommended an increase in the compressions to ventilations ratio to 30:2 (7). There were no published trials in humans to support this change (7). Therefore, we studied this recommendation in our realistic swine model of primary OHCA (24). After 4 min of untreated VF, we found that 24-h neurologically intact survival was greater with CO-CPR than with the then new guidelines standard CPR of 2:30 (24). Consequently, we continued to recommend CO-CPR for patients with primary cardiac arrest.

SURVIVAL IMPROVED BY TEACHING AND ADVOCATING CO-CPR FOR PRIMARY CARDIAC ARREST: THE ARIZONA EXPERIENCE. After a statewide database tracking outcome of OHCA was established in 2004, a program that advocated and taught CO-CPR was initiated in Arizona by our University of Arizona Sarver Heart Center Resuscitation Research Group and the Save Hearts in Arizona Research and Education (SHARE) program headed by Bentley J. Bobrow, MD,
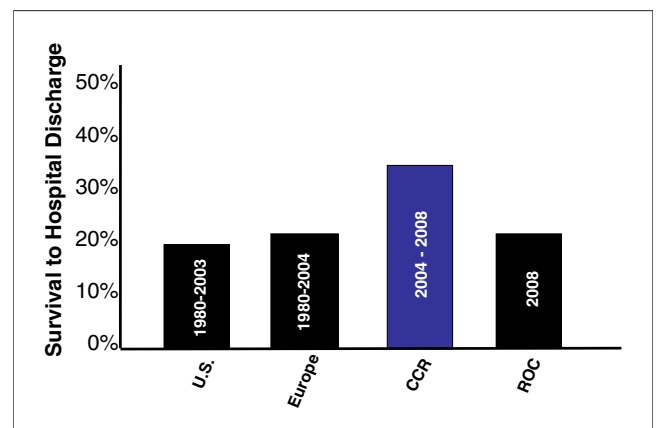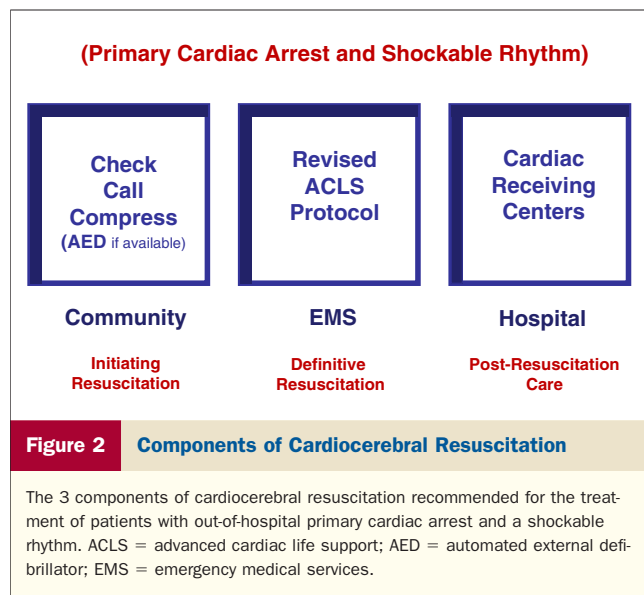

Figure 1   **Average Survival of Patients With VF OHCA**

The average survival rates to hospital discharge of patients with out-of-hospital cardiac arrest (OHCA) due to ventricular fibrillation (VF) displayed by the type of advanced cardiac life support (ACLS) provided by their emergency medical services (EMS). **Black bars** are those following guidelines. The **blue bar** is the average survival with the EMS using cardiocerebral resuscitation (CCR). The years of each analysis is displayed within the bars. ROC = Resuscitation and Outcome Consortium.

(Primary Cardiac Arrest and Shockable Rhythm)

Check Call Compress (AED if available)	Revised ACLS Protocol	Cardiac Receiving Centers
Community	**EMS**	**Hospital**
Initiating Resuscitation	Definitive Resuscitation	Post-Resuscitation Care

Figure 2   Components of Cardiocerebral Resuscitation

The 3 components of cardiocerebral resuscitation recommended for the treatment of patients with out-of-hospital primary cardiac arrest and a shockable rhythm. ACLS = advanced cardiac life support; AED = automated external defibrillator; EMS = emergency medical services.

Medical Director of the Bureau of Emergency Medical Services and Trauma System of the Arizona Department of Health Services. This campaign included flyers to households with their utility bills, articles in newspapers, and radio and television spots, instruction kits for school children, and celebrity endorsements. This was the first large-scale intentional effort to encourage, endorse, and teach CO-CPR to the public (25).

The most important finding of this effort was that persons with the greatest chance of survival, namely, a witnessed collapse and a shockable rhythm (Fig. 3), had a survival rate of 17.7% for those who received conventional CPR by lay bystanders and 33.7% for those who received CO-CPR (25). The overall survival of patients with OHCA was 3.2% without bystander CPR, 7.8% for conventional CPR, and 13.3% for CO-CPR (25). This analysis also identified 2 other major findings: 1) over a 5-year period when CO-CPR was advocated and taught, there was a significant increase in bystander CPR for patients with OHCA, from 28% to 40%; and 2) there was an increase in the likelihood of bystanders choosing to perform CPR to use CO-CPR (20% to 76%) (25).

CO-CPR FOR HEALTH CARE PROFESSIONALS. We also recommend CO-CPR for physicians and health care professionals who encounter primary OHCA. There are 2 reasons for this recommendation. The first is that several studies have reported that physicians and other health care professionals have indicated their reluctance to initiate mouth-to-mouth ventilation on a stranger (14). Perhaps more importantly, even CPR-certified persons who encounter OHCA rarely perform bystander CPR (26). In addition, even health care professionals interrupt chest compressions for prolonged periods (approximately 12 s for medical students and 10 s for paramedics) to provide single rescuer mouth-to-mouth ventilations (27,28).

DISPATCH-ASSISTED CO-CPR. Three randomized controlled trials assessed the effects of teaching CO-CPR by EMS dispatchers. A meta-analysis of these 3 trials reported that survival was statistically better when bystanders of patients with OHCA were given dispatch-assisted CO-CPR as compared with CPR guidelines (29). These findings should encourage all emergency dispatch systems to focus on advocating dispatch-assisted CO-CPR.

The survival of patients with OHCA is greatest in areas that have a high prevalence of bystander CPR. An example of this is in King County, Washington, where their reported survival rate of patients with OHCA presenting with VF was 31% (30). Their incidence of bystander CPR was 61%. They developed a culture of dispatch-assisted CPR (DA-CPR). If one subtracts the approximately 30% of bystander CPR in King County that is the result of DA-CPR, their rates of citizen-initiated bystander CPR is similar to that reported by many other cities. The pioneering researchers and providers of OHCA in King County, Washington, and that recently established by the SHARE program led by Dr. Bentley J. Bobrow in Arizona, offer courses for DA-CPR that the authors highly recommend. Dispatch-assisted CPR that emphasizes CO-CPR for OHCA is perhaps the most practical approach to increase the lay public's performance of bystander CPR as it provides instructions not to the masses, many of whom will never use the procedure, but to the person who needs to perform bystander CPR at the time.

Emergency medical services. The EMS or advanced cardiac life support phase of cardiocerebral resuscitation (Fig. 2) advocates a new sequence of interventions by EMS personnel (Fig. 4) for patients with witnessed arrest and a shockable rhythm (primary OHCA) (14,16). The protocol emphasizes prompt and continual chest compressions before and after a single indicated direct current shock. It delays
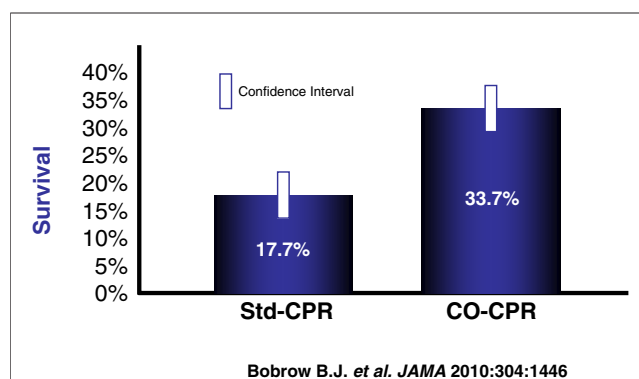
Bobrow B.J. *et al. JAMA* 2010:304:1446

Figure 3   Survival of Patients With Witnessed OHCA Receiving Bystander Resuscitation Efforts

Graphic presentation of the survival to hospital discharge of patients with out-of-hospital cardiac arrest (OHCA) in Arizona between 2004 and 2010. "Std-CPR" is the group who received bystander mouth-to-mouth ventilations plus chest compressions, and "CO-CPR" is the group who received chest compressions only CPR by bystanders.
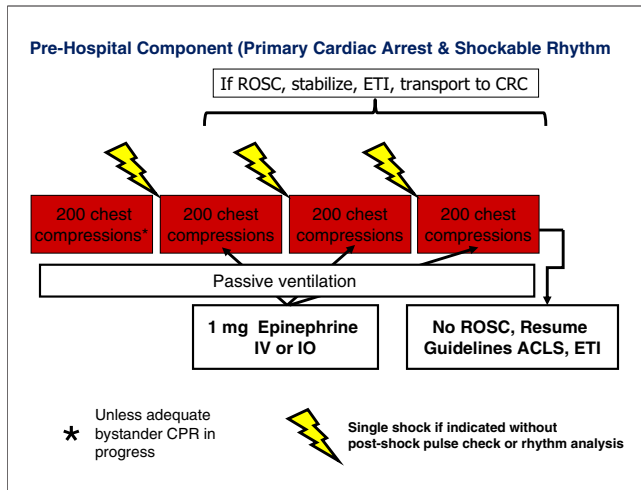
Figure 4   **Cardiocerebral Resuscitation EMS Protocol**

The graphic illustration of the emergency medical services (EMS) component of cardiocerebral resuscitation for the treatment of patients with witnessed primary cardiac arrest and a shockable rhythm. ACLS = advanced cardiac life support; CPR = cardiopulmonary resuscitation; CRC = cardiac receiving center; ETI = endotracheal intubation; IO = intraosseous; IV = intravenous; ROSC = return of spontaneous circulation.

endotracheal intubation (ETI) because of the prolonged interruptions of chest compressions extant during most ETI attempts, in favor of passive ventilation (14,16). Passive ventilation not only prevents the deleterious effects of hyperventilation but also frees up that person to perform other essential duties.

The initial EMS intervention is the prompt initiation of 200 uninterrupted forceful chest compressions at 100 compressions per min allowing full chest wall recoil (14,16,31). By the time most EMS arrives, patients with OHCA due to VF are almost always, unless the arrest was observed by the EMS personnel, no longer in the electrical phase of VF arrest (32). Accordingly, chest compressions are usually necessary before defibrillation for at least 2 reasons. In animal models, the shift of blood volume from the high-pressure arterial system to the low-pressure venous system after VF results in an increased right ventricular volume, a decreased left ventricular volume, and pericardial restraint, and chest compressions before defibrillation improved survival (33,34). In addition, after prolonged untreated VF, CO-CPR before defibrillation increased the electrocardiographic VF frequency and amplitude and was associated with improved survival (35).

Cardiocerebral resuscitation's recommendation of 200 pre-shock chest compressions was a compromise between the 90 s reported by Cobb et al. (13) and the 3 min reported by Wik et al. (36) that resulted in improved survival in patients with OHCA with delayed (>4 min in the Cobb report and 5 min in the Wik report) arrival of the EMS.

After chest compressions, rhythm analysis is followed by a prompt single defibrillation shock (when indicated), followed immediately by another 200 post-shock chest com-

pressions before pulse check or rhythm reanalysis (Fig. 4). Upon the return of spontaneous circulation (ROSC), the patient is usually provided an advanced airway, stabilized, and ideally, transported to a cardiac receiving center hospital (Fig. 4).

RATIONALE FOR EMS COMPONENT OF CARDIOCEREBRAL RESUSCITATION. In the absence of early defibrillation, the most important intervention to improve initial survival of animals with VF was the early generation of adequate coronary perfusion pressures (aortic diastolic minus right atrial diastolic pressure) (37). The coronary perfusion pressure is critical to cardiac resuscitation, for just as in sinus rhythm, where the vast majority of coronary blood flow occurs in diastole, blood flow to the heart during chest compressions for cardiac arrest occurs during the release (or diastolic phase) of chest compressions. During resuscitation efforts of cardiac arrest, if the generated coronary perfusion pressure is low, the animal cannot be resuscitated (37). If intermediate, the animal has ROSC but does not survive 24 h. Similar findings have been reported in humans (38). If good coronary perfusion pressure is generated, the animal can be resuscitated and survive (37).

The recommendation for resuming chest compressions immediately after a defibrillation shock without an analysis of the electrocardiogram or searching for a pulse is another crucial step (Fig. 4) that cardiocerebral resuscitation instituted in 2003 (14,15). It was a common scenario for medical professionals, upon seeing QRS complexes on the electrocardiogram monitor after the electrical shock, to halt chest compressions to search for a pulse. However, while they are searching for a pulse, the post-defibrillation pulseless electrical activity heart that does not receive chest compressions will usually deteriorate into asystole (39). The attempted resuscitation is restarted, but now for a nonshockable rhythm; whereas patients with pulseless electrical activity who receive immediate chest compressions after a successful defibrillator shock are more likely to have an augmented arterial pressure and gradually develop a perfusion rhythm.

ENDOTRACHEAL INTUBATION DELAYED. Endotracheal intubation was initially prohibited as this procedure often delays and interrupts chest compressions (the patient's heartbeat during cardiac arrest) for such prolonged periods that it often precludes survival. This component of cardiocerebral resuscitation, initiated in 2003, was based on our in-hospital experience of observing the cessation of chest compressions for prolonged periods while ETI was being performed (14,15). We assumed that this was the case with EMS systems treating OHCA as well. Years later, Wang et al. (40) reported the durations that paramedics interrupted chest compressions for ETI in 100 patients with OHCA. The median duration of interruption of compressions was 47 s; one-third exceeded 1 min and one-fourth exceeded 3 min (40). These durations of no cerebral blood flow late in a cardiac arrest practically precludes a neurologically intact survival.

If the person with primary VF (witnessed arrest and a shockable rhythm) does not have ROSC after 3 sequences of 200 chest compressions, analysis with or without shock, followed by another 200 chest compressions, advanced airway management is recommended (Fig. 4). If the patient is gasping, intubation is delayed no matter how long the resuscitation attempt, as gasping results in physiologic respirations with a decrease in intrathoracic pressures and increased survival.

PASSIVE VENTILATIONS RECOMMENDED EARLY. Why the recommendation for passive ventilation? Why not bag-valve-mask ventilation? The interruption of chest compressions is not the only adverse effect of positive pressure ventilation. During resuscitation efforts, the forward blood flow from chest compressions is so marginal that providing excessive positive pressure ventilation increases the pressure inside the chest, decreasing blood return and survival (41,42). And to make matters worse, during the resuscitation efforts of patients with cardiac arrest, hyperventilation is common. The editorial, "Death by Hyperventilation," by Aufderheide and Lurie (42), focused attention on this important issue. So when positive pressure ventilation is indicated, volume is controlled, and timing device to limit the number of ventilations is recommended.

To limit "death by hyperventilation," when we instituted cardiocerebral resuscitation in the Rock and Walworth counties of Wisconsin in 2004, the paramedics were instructed to use passive ventilation (16). When we advocated cardiocerebral resuscitation to the medical directors of EMS systems in the cities in the greater Phoenix area in 2005, the EMS that elected to institute cardiocerebral resuscitation were given the choice of providing passive ventilation (oropharyngeal airway insertion and high-flow oxygen by non-rebreather facemask) or bag-valve-mask ventilation (by paramedics at 8 breaths per min). These results were reported as "minimally interrupted cardiac resuscitation" (17). We subsequently analyzed the survival of patients who were and were not treated with passive ventilation. Neurologically intact survival was significantly better (38.2%) among those who received passive ventilation than among those who received bag-valve-mask ventilation (25.8%) (18). This is another example of CQI to continually try to improve survival of patients with primary OHCA.

EPINEPHRINE ADMINISTRATION DURING CARDIAC ARREST. Cardiocerebral resuscitation advocated the early administration of epinephrine (Fig. 4). This recommendation was also based on our animal models of OHCA secondary to VF arrest, where survival was improved with early administration of epinephrine (43).

Cardiac receiving centers. The third major component of cardiocerebral resuscitation (Fig. 2) is the designation of hospitals with a commitment and expertise in caring for the patients with ROSC as cardiac receiving centers. Cardiac receiving center (better terminology), like trauma center, is a special designation of hospitals in Arizona who are committed to therapeutic hypothermia, early cardiac catheterization, delaying the withdrawal of care in comatose patients after ROSC who received therapeutic mild hypothermia, and other aspects of the care of the post-arrest patient. The results of therapy for patients with ROSC following OHCA in cardiac receiving centers in Arizona have yet to be formally published.

Study limitations. The theme of this paper is that implementation of a CQI model in communities may improve survival of OHCA cardiac arrest patients. We cannot say for sure whether the survival benefits seen in Arizona were the result of the specific interventions used or the CQI process itself. In our published studies, we tried to look at the specific interventions over 5 years and control for other factors (17). However, it is possible that the CQI process itself was the key to improved survival. Either way, we recommend that communities that do not have optimal survival for OHCA treated according to guidelines consider implementation of a CQI process.

Conclusions

Because of the poor survival rate extant when following the then national and international guidelines for resuscitation of patients with primary OHCA, in 2003, we used the CQI approach to address this major public health problem. This alternative approach, called cardiocerebral resuscitation, was based not only on the scientific literature in humans but also on extensive laboratory experimentation. In each area of the United States where instituted, cardiocerebral resuscitation resulted in significant improvement in the survival of patients with primary OHCA. Cardiocerebral resuscitation may not be necessary for those communities that obtain good survival rates by following the guidelines.

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