Continuous-Chest-Compression Cardiopulmonary Resuscitation for Cardiac Arrest

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It is well known that out-of-hospital sudden cardiac death is a leading public health problem in the industrialized world. In the absence of early defibrillation, survival rates of patients with out-of-hospital cardiac arrest (OHCA) in most areas of the world are dismal and, except for a recent report of an improved rate of survival when their paramedic protocol was changed, have remained essentially unchanged.1,2

Why have survival rates not improved? One possibility is that the guidelines are not optimal. The guidelines advocate the same approach for 2 entirely different pathophysiological conditions: respiratory arrest in which severe arterial hypoxia and hypotension eventually lead to secondary cardiac arrest, and primary cardiac arrest in which the arterial blood is fully saturated with oxygen at the time of the arrest.1 Mouth-to-mouth ventilations, although appropriate for respiratory arrest, are not, as will be reviewed, essential for survival in the vast majority of patients with OHCA. The recommendation for so-called rescue breathing is a major impediment to performing the crucial first link in the chain of survival.3 Only about a quarter of individuals with OHCA receive bystander resuscitation efforts before the arrival of emergency medical services personnel.4

Cardiopulmonary resuscitation (CPR) is traditionally defined as chest compressions plus ventilations. The need for chest compressions is unquestionable, but the need for or advisability of mouth-to-mouth ventilations for cardiac arrest has been questioned. Two articles in this issue of Circulation, one by Iwami and associates5 from Osaka, Japan, and the other by Bohm and colleagues6 from Sweden, report that the survival rates of patients with OHCA were similar in those who received bystander chest compressions alone and those who received traditional CPR.

Although important, these findings are not new. They do, however, add to the previous reports by Bossaert et al7 in 1989, Van Hoeyweghen et al8 in 1993, and Hallstrom et al9 in 2000, which showed that the survival rate of patients with OHCA with bystander-initiated chest compressions alone or continuous-chest-compression (CCC) CPR was not significantly different from that of patients who received standard CPR.7–9 Because most individuals with OHCA have little chance of surviving, the most helpful information comes from the subset of patients with a chance of survival—those with witnessed arrest and a shockable rhythm on arrival of the paramedics. Thus, the Utstein Osaka Project report by Iwami and associates5 in this issue of Circulation is a very important addition to the findings of the SOS-KANTO study because both showed that the rate of survival with CCC CPR in this subgroup of patients was as good as or, if initiated early, perhaps better than with standard CPR (Table).5,10

Will these reports finally be enough to result in guideline changes in the near future, or as suggested by the authors of the Swedish study, should this decision await the published outcome of randomized trials of CCC and CPR now underway?20 My conclusion is that guideline changes should be made as soon as possible because they are long overdue.11–13

Research in a nonparalyzed swine model of OHCA has long indicated that the most important determinant of 24-hour neurologically normal function after prolonged ventricular fibrillation arrest is the perfusion pressures produced by chest compressions before defibrillation.14 If the perfusion pressures were low, the animal could not be resuscitated; if intermediate, the animal could be resuscitated but would not survive 24 hours; but if high, the animal would survive 24 hours and likely be neurologically normal.4

If arterial perfusion pressures produced by chest compressions are central to survival and if bystanders are not doing chest compressions because of their aversion to or the complicated nature of mouth-to-mouth ventilations, we hypothesized that CCC without ventilation would result in better neurologically normal survival than activation of the emergency medical system and standing by until arrival of professional emergency medical system rescuers. In a 1993 study using our swine model of OHCA, 24-hour neurologically normal survival from prolonged ventricular fibrillation arrest treated with CCC was significantly better than doing nothing, but to our surprise, survival with CCC was equivalent to the then-standard CPR, in which chest compressions were interrupted after each set of 15 compressions for 4 seconds to deliver the recommended 2 assisted ventilations.4 Between 1993 and 2001, we published 5 additional such studies, and in each, we found that the rate of survival with CCC was equal to the then-standard CPR.4 These findings were not generally accepted, in part because of the concern that the upper airway of swine was more likely to remain patent during cardiac arrest relative to that of humans. Accordingly, in one of these studies, the endotracheal tubes were placed and, in the CCC group, were cross-clamped to

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prevent any air exchange, and again, the rates of survival in the 2 groups were the same.4

In 2000, Asser and associates15 reported that lay individuals certified in basic CPR interrupted chest compressions for an average of 16 seconds to deliver the 2 recommended mouth-to-mouth ventilations. This landmark study led us to further investigate the rate of survival in our swine model of OHCA in which each set of 15 chest compressions was interrupted not by 4 but 16 seconds for delivery of the 2 ventilations—a more realistic simulation of single-rescuer CPR for OHCA. Neurologically normal 24-hour survival was much better with CCC.16

Further concern about the utility of mouth-to-mouth ventilations came from reports of Aufderheide and associates,17 who found that during CPR for cardiac arrest, positive pressure ventilation increases intrathoracic pressure, decreases venous return to the chest, and decreases blood flow to the heart and brain.17 Therefore, so-called rescue breathing not only results in excessive interruption of marginal blood flow produced by chest compressions but also further decreases blood flow to the heart and brain by increasing intrathoracic pressures and thereby decreasing venous return to the chest.17

On the basis of not only these basic CPR findings but also on our studies in advanced cardiac life support and our different interpretation of the cardiac arrest resuscitation research literature, we concluded that we could not in good conscience continue to adhere strictly to the guidelines.4 Therefore, in November 2003, we formally launched the first of several new programs for individuals with OHCA that advocated not only CCC CPR for bystanders but also a new advanced cardiac life support algorithm called cardiorespiratory resuscitation.4 Cardiorespiratory resuscitation has now been shown in both a rural area and a metropolitan area to dramatically improve the survival rate of patients with witnessed collapse and a shockable rhythm on the arrival of emergency medical services.18,19

What barriers are delaying the guidelines from recommending CCC CPR for bystander witnesses of OHCA? Perhaps the first is that it is difficult to change a paradigm. For decades, the “ABCs” (airway, breathing, and circulation) have been advocated for bystander basic life support. In fact, rescue breathing is so ingrained in the popular understanding of CPR that 17% of cardiac arrest patients reported by Bohn et al6 in this issue of Circulation received only mouth-to-mouth ventilations for cardiac arrest—clearly an inappropriate response.

A second barrier to guideline change is the impression that the research or scientific data are insufficient to support a change. Why might one come to this conclusion? The 2000 guidelines introduced a new evidence-based approach to resuscitation science that continued with the publication of the 2005 guidelines.1 This approach ranked publications into levels of evidence and categorized randomized controlled trials in humans as the strongest evidence. Results of animal research were placed sixth, giving them little influence as scientific evidence. Randomized controlled trials in humans with OHCA are almost impossible, however, especially in our litigious society. In fact, almost all of the major randomized resuscitation trials have come from foreign countries.

In our opinion, another factor overlooked in the attempt to make guidelines evidence based is the fact that the previous standards were in effect “grandfathered in,” and only new approaches were required to meet their evidence-based criteria.

Ethics dictate that randomized trials should not be done in humans unless there is adequate support in appropriate animal models to show benefit. What is an appropriate animal model? In our view, animal models of OHCA that paralyze the animals are not appropriate because humans with sudden cardiac arrest are not paralyzed. Also inappropriate are animal or human studies that use surrogate end points such as return of spontaneous circulation, blood flow, or oxygen content measurements as end points.

Outcomes in our animal model of OHCA are much better than those reported in humans because the animals are young and healthy, their chests are more compliant, and our technicians performing chest compressions are highly skilled in the proper technique. Nevertheless, survival studies in our nonparalyzed swine model of OHCA have served us well in directing new approaches in humans that have resulted in better survival rates of patients with OHCA.18,19

Another barrier to the guidelines advocating CCC by bystanders of witnessed cardiac arrest is the assumption that the 2 reports published in this issue of Circulation5,6 and all of the previous surveys are not relevant because the 2005 guideline changed the ventilation-to-compression ratio from 2:15 to 2:30. These changes in the 2005 guidelines were based on consensus rather than survival studies in animals or humans.1

Subsequently, we compared CCC and the 2:30 ratio in our swine model of out-of-hospital ventricular fibrillation arrest and found 24-hour postresuscitation neurologically normal function present in 23 of 33 (70%) animals in the CCC group and in 13 of 31 of animals (42%) in the 2:30 CPR group (P = 0.04).20

It is now well established that the critical issues for good perfusion pressures and blood flow during bystander resuscitation efforts for OHCA are the force of compressions, full recoil of the chest wall after each compression, rate of compressions, and minimized interruptions of chest compressions. These can be accomplished with CCC CPR.

Public education and training in CCC CPR are much simpler. We advocate the approach outlined in the Cardiology Patient Page in the present issue of Circulation.21

Advocating and teaching CCC CPR to bystanders should significantly increase bystander-initiated resuscitation efforts and thereby give patients a better chance of survival. We should continue instruction in CPR for the equally important

### Table. Survival From Out-of-Hospital Witnessed Arrest With a Shockable Rhythm

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<th>No CPR</th>
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Values are given as n/N (%).
but much less frequent causes of out-of-hospital cardiac arrest, such as drowning and other forms of respiratory arrest.

It is interesting that CCC CPR, a technique that has not been advocated or taught and is most often performed by individuals not trained in CPR, results in a survival rate similar to that of our guidelines-advocated approach, on which millions of hours and millions of dollars have been spent in education and advocacy. Willingness to revisit decisions in the context of changing facts is essential. It is now time for changes in the guidelines.

Disclosures
None.

References

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