Part 3: Overview of CPR

We have always known that CPR is not a single skill but a series of assessments and interventions. More recently we have become aware that cardiac arrest is not a single problem and that the steps of CPR may need to vary depending on the type or etiology of the cardiac arrest. At the 2005 Consensus Conference researchers debated all aspects of detection and treatment of cardiac arrest. Yet the last summation returned to the beginning question: how do we get more bystanders and healthcare providers to learn CPR and perform it well?

Epidemiology

Sudden cardiac arrest (SCA) is a leading cause of death in the United States and Canada.[1–3] Although estimates of the annual number of deaths due to out-of-hospital SCA vary widely,[1,2,4,5] data from the Centers for Disease Control and Prevention estimates that in the United States approximately 330 000 people die annually in the out-of-hospital and emergency department settings from coronary heart disease. About 250 000 of these deaths occur in the out-of-hospital setting.[1,6] The annual incidence of SCA in North America is ≈0.55 per 1000 population.[3,4]

Cardiac Arrest and the Chain of Survival

Most victims of SCA demonstrate ventricular fibrillation (VF) at some point in their arrest.[3–5] Several phases of VF have been described,[7] and resuscitation is most successful if defibrillation is performed in about the first 5 minutes after collapse. Because the interval between call to the emergency medical services (EMS) system and arrival of EMS personnel at the victim's side is typically longer than 5 minutes,[8] achieving high survival rates depends on a public trained in CPR and on well-organized public access defibrillation programs.[9,10] The best results of lay rescuer CPR and automated external defibrillation programs have occurred in controlled environments, with trained, motivated personnel, a planned and practiced response, and short response times. Examples of such environments are airports,[9] airlines,[11] casinos,[12] and hospitals (see Part 4: "Adult Basic Life Support"). Significant improvement in survival from out-of-hospital VF SCA also has been reported in well-organized police CPR and AED rescuer programs.[13]

CPR is important both before and after shock delivery. When performed immediately after collapse from VF SCA, CPR can double or triple the victim's chance of survival.[14–17] CPR should be provided until an automated external defibrillator (AED) or manual defibrillator is available. After about 5 minutes of VF with no treatment, outcome may be better if shock delivery (attempted defibrillation) is preceded by a period of CPR with effective chest compressions that deliver

some blood to the coronary arteries and brain.[18,19] CPR is also important immediately after shock delivery; most victims demonstrate asystole or pulseless electrical activity (PEA) for several minutes after defibrillation. CPR can convert these rhythms to a perfusing rhythm.[20–22]

Not all adult deaths are due to SCA and VF. An unknown number have an asphyxial mechanism, as in drowning or drug overdose. Asphyxia is also the mechanism of cardiac arrest in most children, although about 5% to 15% have VF.[23–25] Studies in animals have shown that the best results for resuscitation from asphyxial arrest are obtained by a combination of chest compressions and ventilations, although chest compressions alone are better than doing nothing.[26,27]

Differences in CPR Recommendations by Age of Victim and Rescuer

Simplification

The authors of the *2005 AHA Guidelines for CPR and ECC* simplified the BLS sequences, particularly for lay rescuers, to minimize differences in the steps and techniques of CPR used for infant, child, and adult victims. For the first time, *a universal compression-ventilation ratio (30:2) is recommended for all single rescuers of infant, child, and adult victims (excluding newborns)*.

Some skills (eg, rescue breathing without chest compressions) will no longer be taught to lay rescuers. The goal of these changes is to make CPR easier for all rescuers to learn, remember, and perform.

Differences in CPR for Lay Rescuers and Healthcare Providers

Differences between lay rescuer and healthcare provider CPR skills include the following:

- *Lay rescuers* should immediately begin cycles of chest compressions and ventilations after delivering 2 rescue breaths for an unresponsive victim. Lay rescuers are not taught to assess for pulse or signs of circulation for an unresponsive victim.
- *Lay rescuers* will not be taught to provide rescue breathing without chest compressions.
- The lone *healthcare provider* should alter the sequence of rescue response based on the most likely etiology of the victim's problem.
  — *For sudden*, collapse in victims of all ages, the lone healthcare provider should telephone the emergency response number and get an AED (when readily available) and then return to the victim to begin CPR and use the AED.
  — For unresponsive victims of all ages with likely *asphyxial* arrest (eg, drowning) the lone healthcare provider should deliver about 5 cycles (about 2 minutes) of CPR before leaving the victim to telephone the emergency response number and get the AED. The rescuer should

then return to the victim, begin the steps of CPR, and use the AED.

- After delivery of 2 rescue breaths, *healthcare providers* should attempt to feel a pulse in the unresponsive, non-breathing victim for no more than 10 seconds. If the provider does not definitely feel a pulse within 10 seconds, the provider should begin cycles of chest compressions and ventilations.
- *Healthcare providers* will be taught to deliver rescue breaths without chest compressions for the victim with respiratory arrest and a perfusing rhythm (ie, pulses). Rescue breaths without chest compressions should be delivered at a rate of about 10 to 12 breaths per minute for the adult and a rate of about 12 to 20 breaths per minute for the infant and child.
- *Healthcare providers* should deliver cycles of compressions and ventilations during CPR when there is no advanced airway (eg, endotracheal tube, laryngeal mask airway [LMA], or esophageal-tracheal combitube [Combitube]) in place. Once an advanced airway is in place for infant, child, or adult victims, 2 rescuers no longer deliver "cycles" of compressions interrupted with pauses for ventilation. Instead, the compressing rescuer should deliver 100 compressions per minute continuously, without pauses for ventilation. The rescuer delivering the ventilations should give 8 to 10 breaths per minute and should be careful to avoid delivering an excessive number of ventilations. The 2 rescuers should change compressor and ventilator roles approximately every 2 minutes to prevent compressor fatigue and deterioration in quality and rate of chest compressions. When multiple rescuers are present, they should rotate the compressor role about every 2 minutes. The switch should be accomplished as quickly as possible (ideally in less than 5 seconds) to minimize interruptions in chest compressions.

Age Delineation

Differences in the etiology of cardiac arrest between child and adult victims necessitate some differences in the recommended resuscitation sequence for infant and child victims compared with the sequence used for adult victims. Because there is no single anatomic or physiologic characteristic that distinguishes a "child" victim from an "adult" victim and no scientific evidence that identifies a precise age to initiate adult rather than child CPR techniques, the ECC scientists made a consensus decision for age delineation that is based largely on practical criteria and ease of teaching.

In these 2005 guidelines the recommendations for newborn CPR apply to newborns in the first hours after birth until the newborn leaves the hospital. Infant CPR guidelines apply to victims less than approximately 1 year of age.

Child CPR guidelines for the *lay rescuer* apply to children about 1 to 8 years of age, and adult guidelines for the lay rescuer apply to victims about 8 years of age and older. To simplify learning for lay rescuers retraining in CPR and AED apropos the 2005 guidelines, the same age divisions for children are used in the 2005 guidelines as in the *ECC Guidelines 2000*.[28]

Child CPR guidelines for *healthcare providers* apply to victims from about 1 year of age to the onset of adolescence or puberty (about 12 to 14 years of age) as defined by the presence of secondary sex characteristics. Hospitals (particularly children's hospitals) or pediatric intensive care units may choose to extend the use of Pediatric Advanced Life Support (PALS) guidelines to pediatric patients of all ages (generally up to about 16 to 18 years of age) rather than use onset of puberty for the application of ACLS versus PALS guidelines.

Use of AED and Defibrillation for the Child

When treating a child *found* in cardiac arrest in the out-of-hospital setting, *lay rescuers and healthcare providers* should provide about 5 cycles (about 2 minutes) of CPR before attaching an AED. This recommendation is consistent with the recommendation published in 2003.[29] As noted above, most cardiac arrests in children are not caused by ventricular arrhythmias. Immediate attachment and operation of an AED (with hands-off time required for rhythm analysis) will delay or interrupt provision of rescue breathing and chest compressions for victims who are most likely to benefit from them.

If a healthcare provider *witnesses* a *sudden* collapse of a child, the healthcare provider should use an AED as soon as it is available.

There is no recommendation for or against the use of AEDs for infants (<1 year of age).

Rescuers should use a pediatric dose-attenuating system, when available, for children 1 to 8 years of age. These pediatric systems are designed to deliver a reduced shock dose that is appropriate for victims up to about 8 years of age (about 25 kg [55 pounds] in weight or about 127 cm [50 inches] in length). A conventional AED (without pediatric attenuator system) should be used for children about 8 years of age and older (larger than about 25 kg [55 pounds] in weight or about 127 cm [50 inches] in length) and for adults. A pediatric attenuating system should *not* be used for victims 8 years of age and older because the energy dose (ie, shock) delivered through the pediatric system is likely to be inadequate for an older child, adolescent, or adult.

For in-hospital resuscitation, rescuers should begin CPR immediately and use an AED or manual defibrillator as soon as it is available. If a manual defibrillator is used, a defibrillation dose of 2 J/kg is recommended for the first shock and a dose of 4 J/kg for the second and subsequent shocks.

Sequence

If more than one person is present at the scene of a cardiac arrest, several actions can occur simultaneously. One or more trained rescuers should remain with the victim to begin the steps of CPR while another bystander phones the emergency response system and retrieves an AED (if available). If a lone rescuer is present, then the sequences of actions described below are recommended. These sequences are described in more detail in Part 4: "Adult Basic Life Support," Part 5: "Electrical Therapies," and Part 11: "Pediatric Basic Life Support."

For the unresponsive adult, the *lay rescuer* sequence of action is as follows:

- The lone rescuer should telephone the emergency response system and retrieve an AED (if available). The rescuer should then return to the victim to begin CPR and use the AED when appropriate.
- The lay rescuer should open the airway and check for normal breathing. If no normal breathing is detected, the rescuer should give 2 rescue breaths.
- Immediately after delivery of the rescue breaths, the rescuer should begin cycles of 30 chest compressions and 2 ventilations and use an AED as soon as it is available.

For the unresponsive infant or child, the *lay rescuer* sequence for action is as follows:

- The rescuer will open the airway and check for breathing; if no breathing is detected, the rescuer should give 2 breaths that make the chest rise.
- The rescuer should provide 5 cycles (a cycle is 30 compressions and 2 breaths) of CPR (about 2 minutes) before leaving the pediatric victim to phone 911 and get an AED for the child if available. The reasons for immediate provision of CPR are that asphyxial arrest (including primary respiratory arrest) is more common than sudden cardiac arrest in children, and the child is more likely to respond to, or benefit from, the initial CPR.

In general, the rescue sequence performed by the *healthcare provider* is similar to that recommended for the lay rescuer, with the following differences:

- If the lone healthcare provider witnesses the *sudden* collapse of a victim of any age, after verifying that the victim is unresponsive the provider should first phone 911 and get an AED if available, then begin CPR and use the AED as appropriate. *Sudden* collapse is more likely to be caused by an arrhythmia that may require shock delivery.
- If the lone healthcare provider is rescuing an unresponsive victim with a likely *asphyxial* cause of arrest (eg, drowning), the rescuer should provide 5 cycles (about 2 minutes) of CPR (30 compressions and 2 ventilations) before leaving the victim to phone the emergency response number.
- As noted above, the healthcare provider will perform some skills and steps that are not taught to the lay rescuer.

Checking Breathing and Rescue Breaths

Checking Breathing

When lay rescuers check breathing in the unresponsive adult victim, they should look for *normal* breathing. This should help the lay rescuer distinguish between the victim who is breathing (and does not require CPR) and the victim with agonal gasps (who is likely in cardiac arrest and needs CPR). Lay rescuers who check breathing in the infant or child should look for the presence or absence of breathing. Infants and children often demonstrate breathing patterns that are not normal but are adequate.

The healthcare provider should assess for adequate breathing in the adult. Some patients will demonstrate inadequate breathing that requires delivery of assisted ventilation. Assessment of circulation in the infant and child is taught in the PALS Course.

Rescue Breaths

Each rescue breath should be delivered in 1 second and should produce visible chest rise. Other new recommendations for rescue breaths are these:

- Healthcare providers should take particular care to provide *effective* breaths in infants and children because asphyxial arrest is more common than sudden cardiac arrest in infants and children. To ensure that a rescue breath is effective, it may be necessary to reopen the airway and reattempt ventilation. The rescuer may need to try a couple of times to deliver 2 effective breaths for the infant and child.
- When rescue breaths are provided without chest compressions to the victim with a pulse, the healthcare provider should deliver 12 to 20 breaths per minute for an infant or child and 10 to 12 breaths per minute for an adult.
- As noted above, once an advanced airway is in place (eg, endotracheal tube, Combitube, LMA) during 2-rescuer CPR, the compressor should provide 100 compressions per minute without pausing for ventilation, and the rescuer delivering breaths should deliver 8 to 10 breaths per minute.

Chest Compressions

Both lay rescuers and healthcare providers should deliver chest compressions that depress the chest of the infant and child by one third to one half the depth of the chest. Rescuers should *push hard, push fast* (rate of 100 compressions per minute), allow complete chest recoil between compressions, and minimize interruptions in compressions for all victims.

Because children and rescuers can vary widely in size, rescuers are no longer instructed to use a single hand for chest compression of all children. Instead the rescuer is instructed to use 1 hand or 2 hands (as in the adult) as needed to compress the child's chest to one third to one half its depth.

Lay rescuers should use a 30:2 compression-ventilation ratio for all (infant, child, and adult) victims. *Healthcare providers* should use a 30:2 compression-ventilation ratio for all 1-rescuer and all adult CPR and should use a 15:2 compression-ventilation ratio for infant and child 2-rescuer CPR.

For the Infant

Recommendations for lay rescuer and healthcare provider chest compressions for infants (up to 1 year of age) include the following:

- Lay rescuers and healthcare providers should compress the infant chest just below the nipple line (on lower half of sternum).
- Lay rescuers will use 2 fingers to compress the infant chest with a compression-ventilation ratio of 30:2.
- The lone healthcare provider should use 2 fingers to compress the infant chest.
- When 2 healthcare providers are performing CPR, the compression-ventilation ratio should be 15:2 until an advanced airway is in place. The healthcare provider who is compressing the chest should, when feasible, use the 2-thumb–encircling hands technique.

For the Child

Recommendations for lay rescuer and healthcare provider compressions for child victims (about 1 to 8 years of age) include the following:

Summary of BLS ABCD Maneuvers for Infants, Children, and Adults (Newborn Information Not Included)

Maneuver	Adult Lay rescuer: ≥8 years HCP: Adolescent and older	Child Lay rescuers: 1 to 8 years HCP: 1 year to adolescent	Infant Under 1 year of age
Airway	Head tilt–chin lift (HCP: suspected trauma, use jaw thrust)		
Breathing Initial	2 breaths at 1 second/breath	2 effective breaths at 1 second/breath	
HCP: Rescue breathing without chest compressions	10 to 12 breaths/min (approximate)	12 to 20 breaths/min (approximate)	
HCP: Rescue breaths for CPR with advanced airway	8 to 10 breaths/min (approximately)		
Foreign-body airway obstruction	Abdominal thrusts		Back slaps and chest thrusts
Circulation HCP: Pulse check (≤10 sec)	Carotid		Brachial or femoral
Compression landmarks	Lower half of sternum, between nipples		Just below nipple line (lower half of sternum)

Compression method
  Push hard and fast
  Allow complete recoil
	Heel of one hand, other hand on top	Heel of one hand or as for adults	2 or 3 fingers
			HCP (2 rescuers):
			2 thumb–encircling hands

Compression depth	1½ to 2 inches	Approximately one third to one half the depth of the chest	
Compression rate	Approximately 100/min		
Compression-ventilation ratio	30:2 (one or two rescuers)	30:2 (single rescuer) HCP: 15:2 (2 rescuers)	
Defibrillation AED	Use adult pads Do not use child pads	Use AED after 5 cycles of CPR (out of hospital). Use pediatric system for child 1 to 8 years if available **HCP: For sudden collapse (out of hospital) or in-hospital arrest use AED as soon as available.**	No recommendation for infants <1 year of age

Note: Maneuvers used by only Healthcare Providers are indicated by "HCP."

- Lay rescuers should use a 30:2 compression-ventilation ratio for CPR for all victims.
- Rescuers should compress over the lower half of the sternum, at the nipple line (as for adults).
- Lay rescuers should use 1 or 2 hands, as needed, to compress the child's chest to one third to one half the depth of the chest.
- Lay rescuers and lone healthcare providers should use a compression-ventilation ratio of 30:2.
- Healthcare providers (and all rescuers who complete the healthcare provider course, such as lifeguards) performing 2-rescuer CPR should use a 15:2 compression-ventilation ratio until an advanced airway is in place.

For the Adult

Recommendations for lay rescuer and healthcare provider chest compressions for adult victims (about 8 years of age and older) include the following:

- The rescuer should compress in the center of the chest at the nipple line.
- The rescuer should compress the chest approximately 1½ to 2 inches, using the heel of both hands.

Comparison of CPR skills used for adult, child, and infant victims are highlighted in the Table.

CPR for Newborns

Recommendations for the *newborn* are different from recommendations for infants. Because most providers who care for newborns do not provide care to infants, children, and adults, the educational imperative for universal or more uniform recommendations is less compelling. There are no major changes from the *ECC Guidelines 2000* recommendations for CPR in newborns[28]:

- The rescue breathing rate for the newborn infant with pulses is approximately 40 to 60 breaths per minute.
- When providing compressions for newborn infants, the rescuer should compress to one third the depth of the chest.
- For resuscitation of the newborn infant (with or without an advanced airway in place), providers should deliver 90 compressions and 30 ventilations (about 120 events) per minute.
- Rescuers should try to avoid giving simultaneous compressions and ventilations.

Important Lessons About CPR

What have we learned about CPR? To be successful, CPR must be started as soon as a victim collapses, and we must therefore rely on a trained and willing public to initiate CPR and call for professional help and an AED. We have learned that when these steps happen in a timely manner, CPR makes

a difference.[30–32] Sadly we have also learned that bystander CPR is performed in about only a third of witnessed arrests or fewer[31,32] and that when CPR is performed, even by professionals, it is often not done well. Excessive ventilation is provided during CPR for victims with advanced airways, with a resulting decrease in cardiac output[33]; compressions are interrupted too frequently,[34–37] with a resulting drop in coronary perfusion pressure and worse outcomes[38–40]; and chest compressions are often too slow and too shallow.

These guidelines have addressed issues of CPR quality by stressing good CPR—"push hard, push fast, allow full chest recoil after each compression, and minimize interruptions in chest compressions," —and by simplifying recommendations to make it easier for lay rescuers and healthcare providers alike to learn, remember, and perform these critical skills. To minimize interruptions, other changes have been made in recommendations regarding CPR and debrillation (see Part 5: Electric Therapies).

Why are bystanders reluctant to perform CPR? We don't have enough data to answer this important question definitively, but a number of possible reasons have been suggested:

- Some claim that CPR has been made too complicated with too many steps that tax the memory. In these guidelines we have tried to simplify the steps whenever the science allows it. For example, the compression-ventilation ratio for lay rescuers is now the same for infants, children, and adults, and the same technique can be used for chest compressions for children and adults.
- Some feel that our training methods are inadequate, and skills retention has been shown to decline fairly rapidly after training.[41] The American Heart Association has established an ECC education subcommittee to find better and more efficient educational methods. We must also try to apply the lessons of self-efficacy from the field of psychology to understand why people with the same knowledge apply it so differently in emergencies.
- Others point out that the public is afraid of transmitted diseases and is reluctant to perform mouth-to-mouth resuscitation.[42–45] The guidelines emphasize that the data shows that transmission of infection is very low.[46] The guidelines encourage anyone who is still concerned about infection to use a barrier device to give ventilations, although simple barrier devices (ie, face shields) may not reduce the risk of bacterial transmission.[47] The guidelines also encourage those who would rather not give mouth-to-mouth ventilations to call for help and start chest compressions only.

About 10% of newborns require some of the steps of CPR to make a successful transition from uterine to extrauterine life. The Neonatal Resuscitation Program (NRP), which is based on these guidelines, has trained more than 1.75 million providers worldwide. The NRP is used throughout the United States and Canada and in many other countries. The educational challenges for resuscitation of the newborn are quite different from those applying to education of rescuers for response to SCA: because most births in the United States occur in hospitals, resuscitations are performed by healthcare personnel.

Quality Improvement

Processes for continuous quality improvement are essential for the success of out-of-hospital and in-hospital resuscitation programs. For out-of-hospital resuscitation programs the Utstein Registries provide templates to facilitate outcome monitoring.[48–51]

In the United States the Joint Commission for the Accreditation of Healthcare Organizations (JCAHO) revised standards for individual in-hospital resuscitation capabilities to include evaluation of resuscitation policies, procedures, processes, protocols, equipment, staff training, and outcome review.[52]

In 2000 the American Heart Association established the National Registry of Cardiopulmonary Resuscitation (NRCPR) to assist participating hospitals with systematic data collection on resuscitative efforts.[53] The objectives of the registry are to develop a well-defined database to document resuscitation performance of hospitals over time. This information can establish the baseline performance of a hospital, target its problem areas, and identify opportunities for improvement in data collection and the resuscitation program in general. The registry is also the largest repository of information on in-hospital cardiopulmonary arrest. For further information about the NRCPR, visit the website: *www.nrcpr.org*.

Medical Emergency Teams (METs)

The concept of Medical Emergency Teams (METs) has been explored as a method to identify patients at risk and intervene to prevent the development of cardiac arrest. METs studied generally consist of a physician and nurse with critical care training. The team is available at all times, with nurses and other hospital staff authorized to activate the team based on specific calling criteria, following implementation of an education and awareness program.

Three supportive before-and-after single center studies (LOE 3)[54–56] documented significant reductions in cardiac arrest rates and improved outcome following cardiac arrest. Two neutral studies (LOE 3)[57,58] documented a trend toward reduction in the rates of adult in-hospital cardiac arrest and improved outcome[57] and a reduction in unplanned ICU admissions.[58] The most recent study, a cluster-randomized controlled trial in 23 hospitals, documented no difference in the composite primary outcome (cardiac arrest, unexpected death, unplanned ICU admission) between 12 hospitals in which a MET system was introduced and 11 hospitals that had no MET system in place (LOE 2).[59]

Introduction of a MET system for adult in-hospital patients should be considered, with special attention to details of implementation (eg, composition and availability of the team, calling criteria, education and awareness of hospital staff, and method of team activation). There is insufficient evidence to make a recommendation on the use of a MET for children. Further research is needed about the critical details of implementation and the potential effectiveness of METs in preventing cardiac arrest or improving other important patient outcomes.

Summary

These guidelines provide simplified information and emphasize the importance and fundamentals of high-quality CPR.

The following chapters provide more detail about the role of CPR, coordination of CPR with defibrillation, the role of CPR in advanced life support, and basic and advanced life support in newborns, infants and children. We hope that with more people learning high-quality CPR technique, more victims of SCA will receive good bystander CPR and thousands of lives will be saved.

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