Part 6: CPR Techniques and Devices

Over the past 25 years a variety of alternatives to standard manual CPR have been developed in an effort to improve ventilation or perfusion during cardiac arrest and ultimately to improve survival. Compared with standard CPR, these techniques and devices typically require more personnel, training, or equipment, or they apply to a specific setting. Maximum benefits are reported when adjuncts are begun early in the treatment of cardiac arrest, so that the use of these alternatives to CPR is often limited to the hospital setting. To date no adjunct has consistently been shown to be superior to standard manual CPR for out-of-hospital basic life support, and no device other than a defibrillator has consistently improved long-term survival from out-of-hospital cardiac arrest. The data reported here is limited to clinical trials, so most animal data is excluded from this section.

CPR Techniques

High-Frequency Chest Compressions

High-frequency ($>$100 per minute) manual or mechanical chest compressions have been studied as a technique for improving resuscitation from cardiac arrest.[1–4] The sparse animal and human data available show mixed results. One clinical trial of 9 patients showed that high-frequency (120 per minute) chest compressions improved hemodynamics over standard CPR (LOE 4).[5] The use of high-frequency chest compressions for cardiac arrest by adequately trained rescue personnel can be considered, but there is insufficient evidence to recommend for or against its use (Class Indeterminate).

Open-Chest CPR

No prospective randomized studies of open-chest CPR for resuscitation have been published. Four relevant human studies were reviewed: 2 were performed to treat in-hospital cardiac arrest following cardiac surgery (LOE 4[6]; LOE 5[7]), and 2 were performed after out-of-hospital cardiac arrest (LOE 4[8]; LOE 5[9]). The observed benefits of open-chest cardiac massage were improved coronary perfusion pressure[9] and increased return of spontaneous circulation (ROSC).[8]

Open-chest CPR should be considered (Class IIa) for patients with cardiac arrest in the early postoperative period after cardiothoracic surgery or when the chest or abdomen is already open (eg, in trauma surgery). For further information about trauma resuscitation, see Part 10.7: "Special Resuscitation Situations: Cardiac Arrest Associated With Trauma."

Interposed Abdominal Compression

The interposed abdominal compression (IAC)-CPR technique uses a dedicated rescuer to provide manual compression of the abdomen (midway between the xiphoid and the umbilicus) during the relaxation phase of chest compression. The purpose is to enhance venous return during CPR.[10,11] When IAC-CPR performed by trained providers was compared with standard CPR for cardiac arrest in the in-hospital setting, IAC-CPR improved ROSC and short-term survival in 2 randomized trials (LOE 1)[12,13] and improved survival to hospital discharge in 1 study.[13] The data from these studies was combined in 2 positive meta-analyses (LOE 1).[14,15] Evidence from 1 randomized controlled trial of out-of-hospital cardiac arrest (LOE 2),[16] however, did not show any survival advantage to IAC-CPR. Although there is 1 pediatric case report[17] of complications, no harm was reported in the other studies, which involved a total of 426 patients.

IAC-CPR may be considered during in-hospital resuscitation when sufficient personnel trained in its use are available (Class IIb). There is insufficient evidence to recommend for or against the use of IAC-CPR in the out-of-hospital setting (Class Indeterminate).

"Cough" CPR

"Cough" CPR is not useful for the treatment of an unresponsive victim,[18–23] and it should not be taught to lay rescuers. Human "cough" CPR has been reported only in awake, monitored patients who developed ventricular fibrillation (VF) or rapid ventricular tachycardia (VT).[20,22,24] Several small case series (LOE 5)[18,20,22,24] reporting experiences in the cardiac catheterization suite suggest that repeated coughing every 1 to 3 seconds during episodes of VF or rapid VT by conscious, supine, monitored patients trained in the technique can maintain a mean arterial pressure $>$100 mm Hg and can maintain consciousness for up to 90 seconds.

The increase in intrathoracic pressure that occurs with coughing generates blood flow to the brain and helps maintain consciousness. Coughing every 1 to 3 seconds for up to 90 seconds after the onset of VF or pulseless VT is safe and effective only in conscious, supine, monitored patients previously trained to perform this maneuver (Class IIb). Defibrillation remains the treatment of choice for VF or pulseless VT.

CPR Devices

Devices to Assist Ventilation

Automatic and Mechanical Transport Ventilators

Automatic transport ventilators (ATVs). One prospective cohort study of 73 intubated patients, most of whom were in cardiac arrest, in an out-of-hospital urban setting showed no difference in arterial blood gas parameters between those ventilated with an ATV and those ventilated with a bag-mask device (LOE 4).[25] Disadvantages of ATVs include the need for an oxygen source and electric power. Thus, providers should always have a bag-mask device available for manual backup. Some ATVs may be inappropriate for use in children $<$5 years of age.

In both the out-of-hospital and in-hospital settings, ATVs are useful for ventilation of adult patients with a pulse who have an advanced airway (eg, endotracheal tube, esophageal-tracheal combitube [Combitube], or laryngeal mask airway [LMA]) in place (Class IIa). For the adult cardiac arrest patient who does not have an advanced airway in place, the ATV may be useful if tidal volumes are delivered by a flow-controlled, time-cycled ventilator without positive end-expiratory pressure (PEEP). If the ATV has adjustable output control valves, tidal volume should be adjusted to make the chest rise (approximately 6 to 7 mL/kg or 500 to 600 mL), with breaths delivered over 1 second. Until an advanced airway is in place, an additional rescuer should provide cricoid pressure to reduce the risk of gastric inflation. Once an advanced airway is in place, the ventilation rate should be 8 to 10 breaths per minute during CPR.

Manually triggered, oxygen-powered, flow-limited resuscitators. In a study of 104 anesthetized nonarrest patients without an advanced airway in place (ie, no endotracheal tube; patients were ventilated through a mask), patients ventilated by firefighters with manually triggered, oxygen-powered, flow-limited resuscitators had less gastric inflation than those ventilated with a bag-mask device (LOE 5).[26] Manually triggered, oxygen-powered, flow-limited resuscitators may be considered for the management of patients who do not have an advanced airway in place and for whom a mask is being used for ventilation during CPR. Rescuers should avoid using the automatic mode of the oxygen-powered, flow-limited resuscitator because it applies continuous PEEP that is likely to impede cardiac output during chest compressions (Class III).

Devices to Support Circulation

Active Compression-Decompression CPR
Active compression-decompression CPR (ACD-CPR) is performed with a hand-held device equipped with a suction cup to actively lift the anterior chest during decompression. It is thought that decreasing intrathoracic pressure during the decompression phase enhances venous return to the heart. As of 2005 no ACD-CPR devices have been cleared by the Food and Drug Administration for sale in the United States.

Results from the use of ACD-CPR have been mixed. In 4 randomized studies (LOE 1[27,28]; LOE 2[29,30]) ACD-CPR improved long-term survival rates when it was used by adequately trained providers for patients with cardiac arrest in the out-of-hospital[27,28] and in-hospital[29,30] settings. In 5 other randomized studies (LOE 1[31–34]; LOE 2[35]), however, no positive or negative effects were observed. In 4 clinical studies (LOE 3)[30,36–38] ACD-CPR improved hemodynamics over standard CPR, and in 1 clinical study (LOE 3)[39] did not. Frequent training seems to be a significant factor in achieving efficacy.[28]

A meta-analysis of 10 trials involving 4162 patients in the out-of-hospital setting (LOE 1)[40] and a meta-analysis of 2 trials in the in-hospital setting (826 patients)[40] failed to document any early or late survival benefit of ACD-CPR over conventional CPR. The out-of-hospital meta-analysis found a large but nonsignificant worsening in neurologic outcome in survivors in the ACD-CPR group, and 1 small study[41] showed

increased incidence of sternal fractures in the ACD-CPR group.

ACD-CPR may be considered for use in the in-hospital setting when providers are adequately trained (Class IIb). There is insufficient evidence to recommend for or against the use of ACD-CPR in the prehospital setting (Class Indeterminate).

Impedance Threshold Device
The impedance threshold device (ITD) is a valve that limits air entry into the lungs during chest recoil between chest compressions. It is designed to reduce intrathoracic pressure and enhance venous return to the heart. In initial studies the ITD was used with a cuffed endotracheal tube during bag-tube ventilation and ACD-CPR.[42–44] The ITD and ACD device are thought to act synergistically to enhance venous return during active decompression.

In recent reports the ITD has been used during conventional CPR[45,46] with an endotracheal tube or face mask. Studies suggest that when the ITD is used with a face mask, it may create the same negative intratracheal pressure as use of the ITD with an endotracheal tube if rescuers can maintain a tight face mask seal.[43,45,46]

In 2 randomized studies (LOE 1)[44,47] of 610 adults in cardiac arrest in the out-of-hospital setting, use of ACD-CPR plus the ITD was associated with improved ROSC and 24-hour survival rates when compared with use of standard CPR alone. A randomized study of 230 adults documented increased admission to the intensive care unit and 24-hour survival (LOE 2)[45] when an ITD was used during standard CPR in patients in cardiac arrest (pulseless electrical activity only) in the out-of-hospital setting. The addition of the ITD was associated with improved hemodynamics during standard CPR in 1 clinical study (LOE 2).[46]

Although increased long-term survival rates have not been documented, when the ITD is used by trained personnel as an adjunct to CPR in intubated adult cardiac arrest patients, it can improve hemodynamic parameters and ROSC (Class IIa).

Mechanical Piston Device
The mechanical piston device depresses the sternum via a compressed gas-powered plunger mounted on a backboard. In 1 prospective randomized study and 2 prospective randomized crossover studies in adults (LOE 2),[48–50] mechanical piston CPR used by medical and paramedical personnel improved end-tidal CO_2 and mean arterial pressure in patients in cardiac arrest in both the out-of-hospital and in-hospital settings.

Mechanical piston CPR may be considered for patients in cardiac arrest in circumstances that make manual resuscitation difficult (Class IIb). The device should be programmed to deliver standard CPR with adequate compression depth at the rate of 100 compressions per minute with a compression-ventilation ratio of 30:2 (until an advanced airway is in place) and a compression duration that is 50% of the compression-decompression cycle length. The device should allow complete chest wall recoil.

Load-Distributing Band CPR or Vest CPR
The load-distributing band (LDB) is a circumferential chest compression device composed of a pneumatically or electri-

cally actuated constricting band and backboard. Evidence from a case control study of 162 adults (LOE 4)[51] documented improvement in survival to the emergency department when LDB-CPR was administered by adequately trained rescue personnel to patients with cardiac arrest in the out-of-hospital setting. The use of LDB-CPR improved hemodynamics in 1 in-hospital study of end-stage patients (LOE 3)[52] and 2 laboratory studies (LOE 6).[53,54] LDB-CPR may be considered for use by properly trained personnel as an adjunct to CPR for patients with cardiac arrest in the out-of-hospital or in-hospital setting (Class IIb).

Phased Thoracic-Abdominal Compression-Decompression CPR With a Hand-Held Device

Phased thoracic-abdominal compression-decompression CPR (PTACD-CPR) combines the concepts of IAC-CPR and ACD-CPR. A hand-held device alternates chest compression and abdominal decompression with chest decompression and abdominal compression. Evidence from 1 prospective randomized clinical study of adults in cardiac arrest (LOE 2)[55] documented no improvement in survival rates with use of PTACD-CPR for assistance of circulation during advanced cardiovascular life support (ACLS) in the out-of-hospital and in-hospital settings. Thus, there is insufficient evidence to support the use of PTACD-CPR outside the research setting (Class Indeterminate).

Extracorporeal Techniques and Invasive Perfusion Devices

Much of the literature showing the effectiveness of extracorporeal CPR (ECPR) includes patients with cardiac disease. ECPR is more successful in postcardiotomy patients than in those with cardiac arrest from other causes (LOE 5).[56] ECPR may be particularly effective for these patients because they are more likely to have a reversible (ie, surgically correctable or short-term) cause of cardiac arrest, and typically they suffer cardiac arrest without preceding multisystem organ failure.

ECPR for induction of hypothermia has been shown to improve survival rates in a small study of patients who arrived at the ED in cardiac arrest and failed to respond to standard ACLS techniques (LOE 5).[57]

ECPR should be considered for in-hospital patients in cardiac arrest when the duration of the no-flow arrest is brief and the condition leading to the cardiac arrest is reversible (eg, hypothermia or drug intoxication) or amenable to heart transplantation or revascularization (Class IIb).[58,59]

Summary

A variety of CPR techniques and devices may improve hemodynamics or short-term survival when used by well-trained providers in selected patients. To date no adjunct has consistently been shown to be superior to standard manual CPR for out-of-hospital basic life support, and no device other than a defibrillator has consistently improved long-term survival from out-of-hospital cardiac arrest.

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