Cardiac arrest is an uncommon event in inpatient and outpatient settings, but because of poor outcomes, it remains 1 of the top 3 causes of death in the United States, accounting for approximately 300,000 deaths per year. Newer technologies and systems, such as automated external defibrillators (AEDs), rapid response teams, and changes to the Basic Life Support (BLS) procedures, have been heavily promoted without evidence of improved outcomes. Although the techniques and tools of resuscitation for cardiac arrest have evolved, the overall goals remain the same: oxygenation, perfusion, treatment of the underlying cause, and prevention of recurrence.

CAUSES OF CARDIAC ARREST

Cardiac arrest is defined as sudden cessation of effective cardiac function. Cardiac arrest can be due to primary cardiac failure or can be an end manifestation of a myriad of heterogeneous medical conditions. Reported incidences vary based on age, gender, race, location of arrest (inpatient or outpatient), methods of identification and documentation, and availability of postmortem studies. Although coronary artery disease accounts for the majority of cases of cardiac arrest in both inpatient and outpatient settings, about one-third of cases of sudden death have noncardiac causes. Identification of the inciting causes, especially reversible causes of cardiac arrest, is necessary to determine therapeutic interventions as well as systems development to decrease the incidence of cardiac arrest (Table 1 on page 140).
Presumed primary causes of cardiac events are responsible for the majority of cardiac arrest cases, although true numbers are difficult to evaluate given poor postmortem data. Ventricular fibrillation (VF) is the most common cause of out-of-hospital cardiac arrests, accounting for 58% to 72% of outpatient arrests. Ventricular fibrillation is much less common in the inpatient setting, accounting for only 25% of inpatient arrests. However, incidences for both appear to be declining in frequency for unclear reasons. Cardiac arrest due to hypoxia or asphyxia (most often from trauma, pulmonary embolism, drug overdose, acute on chronic respiratory failure, and unknown pulmonary failure) is less common in the adult population. Trauma and injury are not infrequent causes of cardiac arrest. Cardiac arrest resulting from direct myocardial injury is most often associated with blunt trauma; however, arrest can also result from secondary effects such as hemorrhagic shock, hypoxia and asphyxiation, or demand myocardial ischemia due to systemic hypoperfusion.

**INPATIENT VS OUTPATIENT CARDIAC ARREST**

Chest compressions and artificial respiration have been the mainstay of cardiopulmonary resuscitation (CPR) since they were introduced in the 1960s. However, management strategies and outcomes following resuscitation attempts differ greatly between settings, such as the unwitnessed arrest with a first aid responder versus the monitored arrest in a coronary care unit. The approach to patients must be tailored to setting and available resources. After careful consideration, providers should direct treatment toward the most likely suspected cause of the arrest.

**OUTPATIENT CPR**

Algorithms such as the Adult Basic Life Support (BLS) system are targeted to untrained personnel in the out-of-hospital setting where an arrest occurs in an area with limited medical resources. Cardiopulmonary resuscitation is the emergency support of the respiratory and circulatory systems, using chest compressions and artificial respiration.
Since its inception, CPR has been shown to improve survival in patients with cardiac and respiratory arrest. However, despite widespread promulgation to the general public, bystander-initiated CPR is delivered in only 15% to 35% of cases. Survival to discharge of patients with out-of-hospital arrests remains poor at 5% to 10%.

Focused mainly on the out-of-hospital, unwitnessed cardiac arrests attended by untrained personnel, current BLS guidelines have been updated to reflect the change in priority from a ventilation-first to a circulation-first approach. This is based on the body of evidence in favor of maximizing chest compressions in CPR. Promotion of a compression-only approach is intended to improve bystander administration of CPR by simplifying the protocol and de-emphasizing the need for rescue breaths, because it is well recognized that bystanders are averse to giving mouth-to-mouth rescue breaths. Initial data indicate that this approach results in increased rates of CPR administration and overall improved survival. Ewy et al showed an overall survival of 78% for patients receiving standard CPR vs. 13.3% for patients receiving compression-only CPR in out-of-hospital cardiac arrests. For those patients with witnessed, shockable out-of-hospital cardiac arrests, survival rates were 18% vs 34% in those patients receiving standard CPR vs compression-only CPR.

INPATIENT CPR

Overall survival of in-hospital cardiac arrests has remained largely unchanged over the last 40 years. Between McGrath’s 25-year review performed in 1987 and a National Registry of Cardiopulmonary Resuscitation review in 2003, the overall survival rate remained 14% to 17%. Modest improvements recently seen likely reflect improved documentation and reporting and a more restrictive approach to the use of CPR with increased use of do-not-resuscitate orders. Nonetheless, although overall survival is low, almost 60% of those who survive have good neurological recovery at the time of hospital discharge.

The cause of cardiac arrest in the inpatient environment is highly variable, which likely contributes to the lower success rates for resuscitation seen as compared with the outpatient environment. Ventricular fibrillation is seen in only 25% of documented cardiac arrests. Inpatient cardiac arrest data also include those patients in the end stages of noncardiac disease who present with shock, respiratory failure, and apnea, leading to bradycardia, pulseless electrical activity, and asystole. These patients are less likely to respond to CPR and defibrillation and have poorer overall prognoses.

The enthusiasm for development of rapid response teams (also known as medical emergency teams or patient-at-risk teams) stems from the observation that patients often exhibit signs of physiological deterioration prior to cardiopulmonary arrest (Table 2 on page 141). Criteria for activation of these teams include threatened airway, apnea/tachypnea, tachycardia/bradycardia, hypotension, change in mental status, seizure, marked decreases in urine output, and physician, nurse, staff, or family concerns. Indeed, implementation of these teams is 1 of the 6 recommendations set forth by the Institute for Healthcare Improvement.

Table 2.

<table>
<thead>
<tr>
<th>Cause</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrhythmia</td>
<td>49</td>
</tr>
<tr>
<td>Acute respiratory insufficiency or compromise</td>
<td>37</td>
</tr>
<tr>
<td>Hypotension</td>
<td>32</td>
</tr>
<tr>
<td>Acute myocardial infarction or ischemia</td>
<td>10</td>
</tr>
<tr>
<td>Metabolic/electrolyte disturbance</td>
<td>10</td>
</tr>
<tr>
<td>Acute pulmonary edema</td>
<td>3</td>
</tr>
<tr>
<td>Acute pulmonary embolism</td>
<td>2</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>2</td>
</tr>
<tr>
<td>Toxicological problem</td>
<td>1</td>
</tr>
</tbody>
</table>

Adapted with permission from Resuscitation.
Improvement's 100,000 Lives campaign; however, data supporting the effectiveness of the team approach in reducing in-hospital deaths are lacking.²²,A²³ A systematic review of the recent literature, including the recent MERIT trial, shows reductions of 17% to 65% in non-ICU treated cardiopulmonary arrests and decreases in unplanned transfers to ICUs; however, overall hospital mortality rates were unchanged.²⁴ Unfortunately, the evidence that exists is markedly heterogeneous, and further study with improved protocol design and standardization is needed. Success of these systems will depend on ongoing education, organizational support, meticulous data collection and review, and ongoing feedback.

RESPIRATORY MANAGEMENT

Oxygen is the primary substrate for aerobic metabolism. Cellular oxygen consumption is dependent on adequate oxygen delivery, which in turn is dependent on hemoglobin concentration, arterial oxygen saturation, and cardiac output. Ensuring adequate cellular oxygenation and ventilation has remained a primary goal of all resuscitative algorithms for both adults and children. Therefore, maintaining a patent airway and ensuring adequate ventilation are the first priorities in managing any critically ill patient. An open airway supports adequate oxygenation and ventilation and is the initial step in preventing hypoxemia. Multiple devices are available to provide supplementary oxygen, including nasal cannula, face mask, and Venturi mask. All require an external oxygen supply that can be provided by either a cylinder or a wall unit.²⁵

Nasal cannula oxygen can be delivered at flow rates between 1 and 6 L/min, providing anywhere between 21% and 44% inspired oxygen content. A simple face mask can provide approximately 6 to 10 L/min and deliver oxygen concentrations between 35% and 60%. Face masks with an attached oxygen reservoir (nonbreathers) can deliver between 6 and 15 L/min, providing anywhere between 80% and 100% inspired oxygen content. A Venturi mask enables a more reliable and controlled delivery system for oxygen concentrations between 24% and 50%. The use of a Venturi mask is indicated in patients who retain carbon dioxide, including those with chronic obstructive pulmonary disease.

For patients who are unable to breathe spontaneously, bag–valve–mask ventilation should be attempted. The bag–valve–mask device, which consists of a self-inflating bag and a nonbreathing valve, provides positive pressure ventilation when used without an advanced airway. Bag–valve–mask ventilation is a challenging skill that requires significant practice for competency. Continued use of this device can produce gastric insufflation and its associated complications, including vomiting and aspiration. When using a bag–valve–mask device, the clinician should insert an oropharyngeal airway to maintain the patient's airway. Patients should be bagged to achieve visible chest rise, which will deliver adequate tidal volumes. Although well-trained health care providers familiar with the bag–valve–mask ventilation technique can often achieve a leak-proof seal between the mask and the face using 1 hand, it is often easier for 2 well-trained, experienced health care providers to work together, one to provide the leak-proof seal between the mask and the face while gently lifting the patient's jaw while the second provider assists ventilation.

Many advanced airway techniques can be used when spontaneous ventilation fails. One is the Combitube (Covidien-Nellcor and Puritan Bennett, Boulder, CO, USA), which is commonly used in the prehospital environment by emergency medical service providers. The Combitube, an invasive device with 2 inflatable balloon cuffs, is inserted without visualization of the vocal cords. Because the tube is more likely to enter the esophagus, the pharyngeal cuff is inflated and the patient is ventilated through the side openings adjacent to the vocal cords and the trachea. The Combitube should not be used in children younger than 16, in patients with a present gag reflex, in patients with suspected esophageal disease, or in patients who have ingested a caustic substance. A more commonly used advanced airway adjunct in the inpatient setting is the laryngeal mask airway (LMA). The LMA is composed of a tube with a cuffed mask-like projection at the end of the tube that is placed over the hypopharynx and then inflated. Cuff inflation pushes the mask against the tracheal opening, allowing air to flow through the tube and into the
either a saline lock or continuous infusion of isotonic fluid can begin. If infusion therapy is begun, the infusion rate needs to be at least 10 cc/h to keep the IV line open. Saline lock systems are particularly helpful in patients who require volume infusion or resuscitation, a large-bore IV (generally a 14- or 16-gauge IV) should be established, again preferentially in the antecubital fossa or the forearm to facilitate rapid fluid administration.

Drugs administered during CPR typically need 1 to 2 minutes to reach the central circulation. Drug administration by bolus injection should be followed by a 20-cc bolus of IV fluids, and, if possible, the extremities should be elevated for 10 to 20 seconds to facilitate delivery of the drug to the central circulation.

If IV access cannot be established, intraosseous (IO) access is preferred. Intraosseous cannulation provides access to the noncompressible venous plexus in the bone marrow and can be achieved within 30 to 60 seconds. This vascular access technique is suitable for all age groups. The technique uses a rigid needle with a stylet to facilitate insertion. Insertion using a needle with a stylet is preferred to avoid clogging the needle device with bone marrow once access has been established. Although many sites are appropriate for IO infusion, the proximal tibia is particularly useful in all age groups. Other appropriate IO insertion sites include the sternum, the distal tibia, the lateral or medial malleolus, the distal radius, and the distal ulna. In general, the technique for insertion involves identifying the tibial tuberosity just below the knee joint. The insertion site is on the flat portion of the tibia approximately 1 to 2 finger breadths below and medial to this bony prominence. The needle should be inserted perpendicular to the tibia and often requires a twisting motion with gentle but firm pressure. The needle should be inserted through the cortical bone until there is a sudden release of resistance. Aspiration of bone marrow contents and blood into the hub of the needle confirms appropriate placement. A test infusion of saline should then be administered to ensure that the IO needle is truly in the marrow space. The presence of swelling at the insertion

ACCESS FOR RESUSCITATION

High-quality CPR and early defibrillation are the top priorities during the management of a cardiac arrest event. No drug given during resuscitation from a cardiac arrest has been clearly demonstrated to improve survival to hospital discharge or improve neurological outcome. Therefore, drug administration is of secondary importance.

In the management of most patients with cardiac arrest, a peripheral IV is preferable for drug and fluid administration. Ideally, this peripheral access should be established in a large vein, preferably an antecubital fossa. Establishment of access in the antecubital fossa or in the lower extremities does not interfere with the administration of CPR. Once vascular access is established,
site following administration of the test dose of saline indicates that the needle is in an inappropriate position. If this occurs, the IO needle should be removed and the procedure attempted in a different bone to minimize the risk for fracture. Dosing of medications is similar for both IV and IO administration. Administration of medications via the IO route should be followed with a 5- to 10-cc injection of normal saline to facilitate delivery into the central circulation. Intraosseous needles should not be inserted in areas of fracture or crush injuries. Additionally, in those conditions where the bone is fragile, IO needle use should be avoided. The complications of IO needle infusions include fractures, compartment syndrome, and osteomyelitis. Careful insertion technique and attention to sterile technique minimize these complications.

Central access is not needed during most resuscitation attempts. With ongoing CPR, establishment of central access can be difficult, particularly in the subclavian or internal jugular positions. However, central access is sometimes needed, and access to the common femoral vein is a viable option. This is also an excellent site for placement of an introducer sheath should large-volume resuscitation be required, such as in cases of traumatic arrest or septic arrest. Insertion of a central line in a noncompressible area is a relative contraindication for patients who may subsequently require fibrinolytic therapy.

Finally, drugs can be administered via the endotracheal route. However, the absorption of drugs given by the endotracheal route is unpredictable, and the optimal dosing is unknown. A typical dose of drugs administered by the endotracheal route is about 2 to 2 1/2 times the dose given by the IV route. All drugs should be diluted in 5 to 10 cc of either sterile water or normal saline and then the drug injected directly into the endotracheal tube. This should be followed by several positive pressure breaths. The following medications can be administered via the endotracheal route for the management of cardiac arrest: atropine, vasopressin, epinephrine, and lidocaine. The mnemonic NAVEL is often used, where N stands for naloxone, which can be administered in patients with respiratory depression due to opiate ingestion.

Under an emergent situation, there is always the possibility that lines are placed with suboptimal sterile technique. Consideration should be given to the early removal of all emergently placed peripheral and central lines as well as early removal of any IO access, once resuscitation has been completed, to avoid subsequent complications.

DEFIBRILLATION

Although the use of the precordial thump is part of the hallowed history of CPR, it is associated with low efficacy. Several studies over the last 5 years show a 1.3% to 1.9% success rate, and this occurs only in patients presenting with ventricular tachycardia. However, given its relative safety, the precordial thump should be considered after a monitored cardiac arrest if a defibrillator is not immediately available.25–28

Defibrillation is deliberate application of electrical current across the myocardiun to induce depolarization and to reinitiate coordinated electrical activity. Historically, defibrillation was performed using monophasic current. New advances in defibrillator science seek to improve outcomes by fine-tuning the timing of shocks, current flow, and energy levels, but outcome data supporting their effectiveness are pending.

Modern defibrillators use biphasic waveforms, which have been shown to have much higher rates of first-shock success than older monophasic devices. Biphasic defibrillators are less susceptible to variations in transthoracic impedance and automatically adjust output to compensate.

Recommendations regarding current used for initial shocks have changed because of waveforms used by modern devices. The prior recommendation of 360 J for initial shock using monophasic current has been decreased to 150 J for biphasic modes. The BIPHASIC trial compared fixed (150-150-150 J) vs escalating (200-300-360 J) current and found that conversion and fibrillation termination rates were greater in the escalating current group in those patients requiring multiple shocks prior to successful
cardioversion. Those requiring only a single shock were found to have equivalent survival rates and adverse effect rates. Therefore, both strategies are acceptable.

Automated External Defibrillators

Given that the majority of outpatient arrests result from VF, these patients benefit from early defibrillation. As defibrillation is one of the few resuscitative procedures shown to improve survival, technologies and systems to enable earlier defibrillation have been developed. Automated external defibrillators have exploded in popularity in the out-of-hospital setting, with widespread distribution to the majority of public settings, including airports, shopping malls, schools, and casinos. Use in these settings has shown clear benefits in survival. Weaver et al. showed an increase in survival to hospital discharge from 19% to 30% in patients who were treated by first responders with AEDs compared with patients who received defibrillation after paramedics arrived. A similar study by O’Rourke et al. examined the rollout of AEDs on airlines and found a survival to hospital discharge rate of 40%. Valenzuela et al. examined the use of AEDs in casinos and found a survival to hospital discharge rate of 53%. Interestingly, in their study, use of surveillance cameras allowed accurate recordings of time of arrest to defibrillation. For those patients who had witnessed cardiac arrest and defibrillation no more than 3 minutes after arrest, survival to hospital discharge was 73%. Use of AEDs has been advocated in the in-hospital setting to decrease times to defibrillation. However, improvements in survival have not been demonstrated, likely because fewer than 20% of patients who arrest in the inpatient setting have a fatal dysrhythmia responsive to defibrillation. Indeed, for these patients, AEDs can delay or interrupt prompt administration of continuous chest compressions and thus lead to lower survival rates.

OUTCOMES

Outcomes in cardiac arrest vary widely between different causes of arrest and the settings in which arrest occurs. Other factors that influence outcome include recognition time, response time of trained personnel, type of cardiac dysrhythmia, and timeliness of chest compressions. Unfortunately, only 15% to 35% of patients receive timely, effective CPR in the out-of-hospital setting, and survival to discharge ranges from 5% to 10%. For every minute that CPR is delayed, a patient’s chance of survival decreases by 7% to 10%.

Significant determinants of outcome include initial rhythm, concurrent cardiac and noncardiac comorbid conditions, and time of day when cardiac arrest occurs. Specific patient factors associated with poor survival include a history of diabetes, pulseless electrical activity or asystole, cardiac arrest during the night, impaired renal function, and dependent functional status. Male gender, compared with female gender, is associated with a higher 1-month survival rate but with similar overall survival rates and poorer overall neurological outcomes. Black patients appear to have lower rates of survival, although whether this is attributable to less frequent use of do-not-resuscitate orders use remains unclear.

HYPOTHERMIA

Therapeutic hypothermia (TH) has been shown in several randomized clinical trials to improve survival and neurological outcomes. The 2 landmark studies were both published in 2002 in the New England Journal of Medicine. Bernard et al. found a 49% rate of normal neurological function after cardiac arrest in patients receiving TH compared with 26% in patients not treated with hypothermia. Similarly, a multicenter European trial found a 55% rate of favorable neurological outcome in patients receiving hypothermia vs 39% in those without hypothermia. However, widespread implementation of this technology has been slow and is hampered by difficulties in adjusting to protocols and technologies and by concerns over adverse effects.

In the setting of cardiac arrest, TH is defined as the controlled lowering of core body temperature to 32°C to 34°C. Temperatures below this are difficult to manage because of shivering, which often requires significant
sedation or neuromuscular blockade. A temperature below this level decreases the threshold for cardiac arrhythmias such as slow atrial fibrillation (<31°C) and VF (<28°C).

Therapeutic hypothermia has been part of international consensus guidelines for resuscitation since 2005. Guidelines by the American Heart Association recommend 12 to 24 hours of hypothermia when the initial rhythm is VF. However, the role of TH in non-VF arrest is unclear. In-hospital cardiac arrests, which have declined with the implementation of medical emergency response teams, are less frequently VF arrests and may have fewer indications for the use of TH. However, the availability of personnel and resources makes early implementation of TH more feasible, and clinicians need to carefully balance the risks of TH with the potential for improved neurological outcome after injury from cardiac arrest. Indications for use of TH in situations such as pediatric cardiac arrest and respiratory arrest leading to cardiac arrest have been poorly studied to date, and TH cannot be recommended in these cases.

Various techniques of induction of hypothermia are under study. Original protocols made use of refrigerated cooling blankets and ice packs. Newer systems include more efficient surface cooling pads, \textsuperscript{93} jackets, and helmets; intravascular cooling systems via an inferior vena cava temperature exchange catheter or large-volume, ice-cold crystalloid fluid infusion; \textsuperscript{12,34} and targeted cerebral cooling via the nasopharyngeal approach. Large-volume, ice-cold crystalloid fluid in particular appears to be a promising approach that minimizes cost, complexity, and time to initiation of TH.

**PREGNANCY AND CARDIAC ARREST**

Cardiac arrest during pregnancy is rare, occurring in about 1 in 30,000 pregnancies. However, cardiac arrest during pregnancy appears to be increasing in frequency, most likely because of increasing risk factors for ischemic cardiac disease in pregnant women, given increasing rates of obesity and increasing age of first pregnancy. Another explanation for increased incidence of cardiac arrest during pregnancy is that patients with congenital heart defects have greater chances of surviving to childbearing years and thus increased likelihood of becoming pregnant. \textsuperscript{55,56} Causes for increased rates of cardiac arrest during pregnancy include hemorrhage, preeclampsia, HELLP syndrome, amniotic fluid embolism, pulmonary embolism, sepsis, trauma, and anesthetic complications. Given low numbers of potential subjects, no large, randomized controlled trials have evaluated different management techniques in the pregnant patient with cardiac arrest, and so guidelines for resuscitation are based on recommendations and data from small, observational studies.\textsuperscript{55,57}

The treatment of the gravid cardiac arrest patient must address the status of the patient in resuscitation. Cardiac output is increased by 1.0 to 1.5 L/min. Systolic blood pressures tend to be 10 to 15 mm Hg lower. There is a decreased hematocrit due to increased plasma volume, leading to physiological anemia of pregnancy. Tidal volume is increased, and there is a decrease in functional residual capacity.

Resuscitation therefore must address the physiological changes that occur in the pregnant patient. The airway must be carefully monitored and secured expeditiously as needed. Fluid resuscitation must be adjusted for the increased plasma volume of pregnancy. Current drug and medication recommendations are not altered in the pregnant patient. Transthoracic impedance is not altered during pregnancy, and current energy settings for defibrillation are unchanged for the pregnant patient. The gravid uterus can cause aortocaval compression that can compromise the venous return of the mother and lead to hemodynamic compromise of the mother and fetus. A left lateral tilt of 15° to 30° is recommended to shift the gravid uterus off the inferior vena cava. Chest compressions can be effectively applied in the maximal 27° left lateral tilt position (such as with the use of the Cardiff wedge) and produce 80% of the force applied in the supine position.\textsuperscript{58}

Perimortem cesarean delivery (PMCD) is recommended only within 4 to 5 minutes of onset of maternal cardiac arrest. However, case series and retrospective cohort
studies suggest that good outcomes are possible even after this 5-minute interval, especially at older gestational ages (30-38 weeks). Multiple case reports document babies born without sequelae after PMCD and return of spontaneous circulation in the mother after evacuation of the uterus. Therefore, if return of spontaneous circulation does not occur in the first 4 minutes, PMCD should be considered when all other resuscitation methods fail. Consideration of PMCD for fetuses below an estimated gestational age of 28 weeks must take into account the available resources and experience of the institution.

**PEDIATRIC CARDIAC ARREST**

Causes for cardiac arrest in the pediatric population differ from those in adults, but outcomes remain poor. In the inpatient setting, most children regain spontaneous circulation and more than 25% survive to discharge. In contrast, only 10% survive to discharge when cardiac arrest occurs out of hospital. Explanations of this include difficulties in performing effective CPR in pediatric patients and differing pathogenesis of cardiac arrest. Coronary artery disease with VF leading to cardiac arrest is rare in children. Cardiac arrest in these patients is more likely unwitnessed, is of prolonged course, and most commonly results from respiratory arrest due to hypoxia or asphyxia or due to circulatory shock and arrest. This underlies the rationale for prolonged immediate CPR prior to notification of emergency medical services and use of AED. Defibrillation is the treatment of choice for VF/pulseless ventricular tachycardia, although the optimal current is unknown. Initial settings of 2 J/kg and subsequent settings of 4 J/kg are generally recommended.

It seems logical that outcomes are related to whether events are witnessed, whether bystander CPR is performed, and the time elapsed to CPR and arrival of emergency medical services, as is the case in adult cardiac arrests; however, data are limited. Cardiac arrest associated with rapid onset of hypothermia or icy water immersion can have good neurological outcomes in pediatric patients despite prolonged (>30 minutes) duration of arrest.

Arrests associated with blunt trauma and septic shock have uniformly poor outcomes in pediatric patients.

**REFERENCES**


