SECTION I

Resuscitation

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No activities in medical care more dramatically typify the "life and death" nature of emergency practice than the efforts to resuscitate victims of cardiopulmonary arrest. Recognition of impending cardiorespiratory collapse, followed by rapid response; and appropriate intervention of educated laypersons are essential if the patient is to receive optimal care. Cardiopulmonary arrest patients must be rapidly turned over to EMS personnel, who further stabilize the patient before passing the patient to hospital-based medical professionals. One recent study of large city populations demonstrated survival rates for cardiac arrest to be as low as 3% to 4%, while another study cited a 71% survival rate of individuals who suffered a witnessed cardiac arrest in a casino, and who were then attended to within 3 minutes by a security guard trained to use an AED. Clearly, a huge opportunity to increase the number of survivors of cardiopulmonary arrest exists.

Consistent education and response capability at all levels—communities, laypersons, first responders, EMTs, RNs, and MDs—should be viewed as a public health imperative. In addition, research into improvement in our techniques—with regard to airway maintenance, effective ventilation, and restriction of an effective cardiac rhythm, while preserving of cerebral function—should be given high priority.

CHAPTER 1

Adult Cardiopulmonary Resuscitation

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Introduction

The science of resuscitation, especially as it applies to victims of sudden cardiopulmonary collapse, has its roots in research conducted in the 1950s and 1960s. In 1966, a conference held under the auspices of the National Academy of Science recommended that cardiopulmonary resuscitation (CPR) be taught to all health care workers. The American Heart Association (AHA) actively took the lead in formulating curricula and training in reviving patients suffering cardiac emergencies. This has evolved over many years and conferences to include greater scientific evidence and international consensus to develop the current recommendations. During an international gathering of physicians and scientists in 2000, attendees looked at the latest scientific data to assess its relative merit for inclusion within a set of international standards for Advanced Cardiac Life Support (ACLS). The results of this conference were published in *Circulation* in 2000. This publication was remarkable for its attempt to place resuscitation into a rigorous scientific framework. The authors of this document characterized the available literature on resuscitation into levels of scientific validity. At the top were Level 1—randomized, double blind, controlled studies—progressing down to Level 3, 4, and 5, representing decreasing levels of evidence and finally anecdotal reports. Recommendations regarding appropriate intervention(s) were therefore based on the scientific evidence available, and on the quality of that evidence.

Recommendations were developed for all levels of providers, including typical pre-hospital personnel, first responders: police and fire personnel trained to do CPR and administer defibrillation via semi-automatic defibrillators (SAEDs) or automated external defibrillators (AEDs); basic emergency medical technicians (EMTs), who have some additional training; and EMT paramedics, who typically have a great deal more training. The scope of practice would encompass active airway management, defibrillation, cardioversion, and cardiac pacing, as well as a full range of cardiac medications. The hospital-based personnel (nurses and physicians) are likewise addressed in the guidelines. The theme is that the survival of any patient suffering from an acute cardiopulmonary arrest is dependent on the actions of many people, acting as a team, each trained and possessing unique and complementary skills, both in and out of the hospital.

This chapter outlines the interventions that are most scientifically valid for patients suffering from cardiac arrest and outlines general guidelines for all patients during the pre-, during, and post-arrest time frames.

Epidemiology of Cardiac Arrest

To understand the scope of the problem, it is necessary to recognize that roughly 1.25 million Americans will suffer myocardial infarctions this year. Of those, approximately 225,000 will suffer sudden cardiac death, dying before they reach the hospital.[1] Patients who experience acute cardiac or pulmonary insults that may or do lead to cardiopulmonary arrest are the focus of the current AHA Guidelines (**Table 1.1**).

The AHA Guidelines emphasize a few new and constantly changing concepts, as well as reinforcing some old ones (new guidelines are “in the works”).

What can be seen at this time is that strict attention to the ABCs—airway, breathing, and circulation—must be of primary importance. Rapidly activating emergency medical services by calling 911; opening the airway and performing immediate CPR; early defibrillation; and rapid access to Advanced Life Support are appropriately stressed as the necessary links in the Chain of Survival. If all four links in this chain take place in a timely manner, survival from cardiac arrest is most likely to occur. By studying and ensuring the robustness of each link, every community can maximize the survivability of its citizens who suffer cardiac arrest. In this effort, the AHA has developed a program to recognize communities that have worked to assure each link in the Chain of Survival is optimized.

Next, antiarrhythmic medications are no longer considered *front line* therapy for such patients. Instead, early interventions with appropriate forms of electrical therapy (cardioversion, pacing, and defibrillation) are considered the cornerstones of intervention. It is only after such actions have failed that medication administration should be considered. Along these lines, emphasis has been placed on early defibrillation, via the positioning of SAED or AED devices where they can easily and quickly be used for patients suffering from sudden cardiac arrest. Options for

Table 1.1

Common Etiologies of Cardiac Arrest in Adults

I. Cardiovascular
- Acute myocardial infarction (usually leading to one of the following):
  - a. Tachyarrhythmias/ventricular tachycardia
  - b. Ventricular fibrillation
  - c. High degree heart blocks
- Pulseless electrical activity
- Tension pneumothorax, pericardial tamponade, pulmonary embolism, hypoxia, hypovolemia, acidosis, electrolyte imbalance, cardiogenic shock, secondary to extensive left ventricular necrosis
- Bradyarrhythmias
- Asystole

II. Pulmonary
- Hypoxia (multiple causes)
- Pulmonary embolism, tension pneumothorax
- Hypercarbia
- Acidosis

III. Endocrine/Metabolic
- Metabolic acidosis
- Other electrolyte imbalance

this include training and equipping first responder agencies (police, fire, lifeguards, security officers and park rangers) with these machines, as well as the more controversial concept of placing public access defibrillations (PADs) in areas for public use.

Once the decision has been made to move to pharmacologic intervention, newer medications such as amiodarone should be considered over older, less well-proven medications, such as lidocaine (bretyllium has been entirely dropped from the resuscitation guidelines). Another medication, which may prove to be useful in resuscitating patients suffering cardiac arrest, is vasopressin, the effect of which, recent research suggests, is similar to epinephrine.

New guidelines are put forth for advanced airway management. Included are emphasis on the laryngeal mask airway (LMA) and the combi-tube as "rescue" airways when endotracheal intubation cannot be accomplished in the pre-hospital environment. In the hospital setting, additional adjuncts, which may facilitate endotracheal intubation are available, these include fiberoptic laryngoscopes, gum elastic (intubating) bougies, and use of paralytic medications.

Once endotracheal intubation has been performed successfully, new guidelines for confirming appropriate tube placement have been put forth. This would involve end tidal CO_2 measurement, either via color change in a colorimetric device or, preferably, via direct measurement of expired CO_2 via a capnometer. Additionally, other devices, such as the esophageal detector device (EDD) utilizing anatomical differences between the trachea and the esophagus, can be used to prevent the inadvertent cannulation of the esophagus rather than the trachea. This is later outlined in further detail.

The treatment of tachyarrhythmia's now emphasizes understanding the underlying rhythm and determining the functioning of the patient's heart, primarily the left ventricle. In patients with poorly functioning left ventricles, medications are likely to be pro-arrhythmic and early electrical intervention is encouraged. For those patients with intact left ventricular function, treatment with a single, most appropriate, medication is emphasized.

The acquisition of pre-hospital 12 lead ECGs is emphasized as a means to more rapidly triage and treat patients with an acute cardiac emergency.

Additionally, pre-hospital use of thrombolytic agents is considered to be beneficial in those patients with prolonged transport time to a hospital. This recommendation is controversial at this time and only those pre-hospital systems with prolonged transport times, and close medical oversight and quality assurance should be considering this intervention.

All patients with acute myocardial infarction (MI) should receive, if there are no contraindications, aspirin and β-blockers. Consideration of administration of angiotensin-converting enzyme inhibitor (ACE) medications in patients with large MIs, low ejection fractions, and left ventricular dysfunction (if not hypotensive), needs to occur in either the emergency department or the intensive care unit.

Finally, primary angioplasty is categorized as a Class 1 intervention in those locations where there is a large volume of angioplasties performed, the time to catheterization is short (<90 minutes), and/or there are contraindications to thrombolytic medications.

General Approach to Patients Who Are in Cardiopulmonary Arrest

The general approach to patients in arrest is similar no matter the etiology. The traditional "airway, breathing, and circulation" assessments are the first priorities.

Airway/Breathing

In patients who are in arrest, an adequate airway must be secured and the patient ventilated with 100% oxygen. This will usually mean placing an endotracheal tube and verifying its position. Multiple organizations have put forward guidelines for verification of endotracheal tube placement. In general, the paramedic or the emergency physician would be well advised to document the following in patients they intubate:

1. Visualization of the endotracheal tube passing through the vocal cords.
2. Some means of end tidal CO_2 measurement. This can be either quantitative via a capnometer or via color change with a colorimetric device.
3. Alternatively, an esophageal detector device (EDD) may be used. This device is designed to take advantage of the relative rigidity of the trachea with its cartilaginous rings and the contrasting characteristic of the esophagus, due to its muscular nature, to collapse when a negative pressure is applied. The EDD

can either be a collapsible bulb attached to an adaptor allowing it to be placed on the end of an endotracheal tube or can be a syringe type of device. By either compressing the bulb or applying negative pressure on the syringe, in either case attached to the endotracheal tube, a negative pressure is introduced into either the esophagus or trachea, whichever is intubated. If in the trachea, the bulb will rapidly inflate or the syringe will allow air to be drawn back due to the rigid nature of the wall. If in the esophagus, the walls will tend to collapse around the tube from the negative pressure and the bulb will either not inflate or very slowly inflate, while the syringe will not allow air to be drawn back.[2] Early studies showed the EDD to be very sensitive and specific.[3] This device may be useful in patients who are in arrest who are not generating enough CO_2 to be measured via capnometer.

4. Equal bilateral breath sounds.
5. Lack of sounds over the epigastrium.
6. Improving vital signs, including pulse oximetry (often not available in an arrest).

Of these, number 1 is the most important or "gold standard" to follow, with number 2 a close second. However, all of these, with the exception of direct visualization, have some potential for being incorrect and mislead the treating health care professional into which orifice is actually intubated. Therefore, it is probably wise to document as many of these as is possible and re-verify the placement of the endotracheal tube after each time the patient is moved (when it is most likely to become dislodged or moved). An additional benefit to measuring end-tidal CO_2 in patients in arrest is that a rising value is suggestive of adequacy of CPR and is always seen in patients who are successfully resuscitated. Conversely, in patients who have a properly placed endotracheal tube, who have been treated to the full extent of ACLS Guidelines for at least 20 minutes, who show end-tidal CO_2 readings of less than 10, survival is virtually 0%.[4]

Although endotracheal intubation is considered the gold standard for managing an airway, all emergency physicians must become skilled at managing an airway with a simple Bag-Valve-Mask (BVM) and with alternative/rescue airways. Such airways, like the laryngeal mask airway, the Combitube, and others will often allow ventilation in patients who cannot be intubated by one means or another. Likewise, familiarity with and competence in surgical airway management, either using a traditional cricothyrotomy set-up or (preferably) one of the commercially available kits (e.g., the Per-Trach, the Melkor/Cook Kit, and others) is mandatory. These kits are readily available and afford the emergency medical physician the opportunity to practice the technique in a number of models.

Recently, newer devices have been developed which may at some point in time replace the traditional BVM. One of these, the Oxylator, an oxygen powered pressure ventilator, has shown great promise. It has been used extensively in Europe and in a few systems in the United States. The advantages of this device are that it is very easy to use, far easier than the traditional BVM and when used appropriately leads to less gastric insufflation. Its disadvantage lies only in that it requires a compressed air or oxygen supply to function.

Circulation

Support of circulation in patients in arrest has, for many years, consisted of chest compressions. Although this has traditionally been done manually, there is at least one product being tested (which may supplant this writing) at least in some places and agencies. There has been some interest in chest-compression-only CPR, with a few studies, using it by otherwise untrained laypersons to allow the patient a potential bridge the first few minutes until first responders and EMS personnel arrive on scene. It is currently unclear if this will become more commonplace in the future. Finally, there have been studies suggesting that the patient suffering an unwitnessed cardiac arrest may do better if 60 to 90 seconds of CPR is performed prior to defibrillation.[5] Again, as mentioned above, it is unclear if this will become the standard of care for EMS and other health care providers.

Medications

For the patient who is in full cardiopulmonary arrest, the list of medications, which are used, is fairly brief. The vasopressor, positive inotropic and chronotropic medication, epinephrine, has long been a centerpiece of resuscitation. Recently the medication vasopressin has shown some promise either supplementing or supplanting epinephrine in arrest situations. However, data leading to improved outcomes is lacking at this time.[6] In addition to its hemodynamic effects, in the patient who is in arrest from angioedema or allergic reaction, leading to airway obstruction, administration of epinephrine may be life saving. The dose of epinephrine for patients in acute cardiac arrest is 1 mg (1:10,000), intravenous push, every 3 to 5 minutes. For patients with an anaphylactic reaction, either subcutaneous (1:1,000) or intravenous routes may be used. The dose sq is 0.3 to 0.5 mg, repeated every 15 to 20 minutes. If administered intravenously, typically when the patient is hypotensive, the usual dose is 0.1 mg slowly over 3 to 5 minutes. The usual dose of vasopressin for patients in cardiac arrest is 40 International Units via slow intravenous push.

Atropine, an anticholinergic medication, decreases the parasympathetic stimulation of the heart, leading to an increase in rate and blood pressure. It is used as well in symptomatic bradycardia, atrio-ventricular blocks, and in patients who are in full cardiac arrest. The usual dosage of atropine is 0.5 to 1 mg intravenously every 3 to 5 minutes to a total dose of 3 mg.

Dopamine is an excellent vasopressor for patients in shock especially after the patient has had adequate fluid resuscitation or adequate fluid resuscitation is contraindicated. It is also useful in the postresuscitaion period for patients in shock. The usual dose of dopamine is to begin an intravenous infusion at 2 to 5 μm/kg/min and titrate to the desired blood pressure, typically a minimum systolic pressure of 100 mm Hg.

In the past few years, amiodarone has re-emerged as an excellent anti-arrhythmic. Its use is indicated in patients with ventricular fibrillation and pulseless ventricular tachycardia refractory to defibrillation. The usual dose of amiodarone is 300 mg via slow intravenous push.

Lidocaine, long the standard in anti-arrhythmic therapy, remains a useful medication. Like amiodarone, its use should be preceded by defibrillation. The standard dose of lidocaine is 1 to 1.5 mg/kg slow intravenous push, the dose being repeated in 3 to 5 minutes with a maximum dose of 3 mg/kg. In between the two "loading" doses, a continuous intravenous infusion of 1 to 4 mg/min should be started.

The choice of fluids used in resuscitation has likewise received much interest within the past 10 years. Traditionally, crystalloids, either normal saline or lactated ringers, have been used. They offer the advantages of being inexpensive, easy to store, and without having significant side effects. Downsides to their use are that they do not carry oxygen and remain in the central circulation for only a relatively brief period of time. This has spurred research into better volume resuscitation fluids.

Among these include colloids and hypertonic saline. Although each has shown promise, neither has shown improved outcomes, tend to be much more expensive and more difficult to store, and have not achieved widespread acceptance.

Blood, although an ideal resuscitation fluid, especially in hypovolemic and traumatic arrest, has significant drawbacks. It is difficult to store, is expensive and in short supply. Additionally, allergic reactions are a real concern. Despite this, there are pre-hospital agencies, primarily air medical services, which routinely carry blood products for resuscitation.

The search for an artificial blood product has gone on for many years. Ideally, such a product would be inexpensive, have a long shelf life, induce few reactions, and markedly improve hemodynamic parameters and oxygen carrying capacity. To date, no product has been found which fulfills all of the above criteria. Despite this, ongoing trials in new products continue.[7]

Electrical Therapy

As stated in the current AHA Guidelines, electrical therapy is considered the cornerstone of resuscitative efforts. Modern devices, such as the Life Pack-12, the Zoll M series, and machines by other manufacturers, offer unparalleled capabilities. Each has unique features recommending it for use. The determination of which device to use should be decided by each system and/or medical director.

Pacing

The ability to transcutaneous pace a patient has extended this ability to many patients both in the field and in the community ED. Classically, the use of pacing is seen in patients with symptomatic bradycardia, Type II second-degree AV blocks and complete (Type III) heart blocks. In addition, overdrive pacing may be used in patients suffering from prolonged QT interval tachycardias and/or torsades de pointes. Finally, transcutaneous pacing may be considered, although it is rarely successful in patients suffering asystolic arrest.

Defibrillation

Of the patients suffering sudden cardiac death, ventricular fibrillation and/or ventricular tachycardia are the predominant rhythms. Early defibrillation has long been, rightly, considered the "gold standard" of care. It has been argued, convincingly, that the earlier defibrillation is accomplished, the better the patient outcome in most circumstances. As stated above, in the unwitnessed cardiac arrest, a minute of CPR may be useful. The most modern defibrillation devices use a biphasic waveform, where the current switches polarity in mid-delivery. Long used for implantable defibrillators and for AEDs, the evidence is increasingly clear that biphasic defibrillation is superior to older monophasic defibrillators. An area of some controversy is the appropriate amount of energy to deliver to the patient. Traditional monophasic defibrillators had fairly routine energy delivery schedules, namely 200 to 300, then 360 joules. One of the potential advantages of biphasic defibrillation is the ability to defibrillate the patient with lower energy settings. This potentially could result in less myocardial damage during the shock and possibly better outcomes (citation). Despite this, different manufacturers of defibrillation equipment tout their different waveforms and energy settings for defibrillation with their device. Some manufacturers mirror the older defibrillation settings, while others limit their devices to lower energy levels. It is to be hoped that the science of resuscitation will resolve these conflicting claims in the next few years.

Cardioversion

Cardioversion, as opposed to defibrillation, assumes an organized cardiac rhythm that does not require total depolarization of the heart to achieve a more stable rhythm. In general, lower energy settings are required. Patients with a supraventricular tachycardia will usually require 50 to 100 joules of energy. Patients with atrial fibrillation require higher levels of energy, typically 100 to 200 joules. Finally, ventricular rhythms, such as stable ventricular tachycardia typically require greater energy settings, 100 to 200 or 300 joules. Just as in defibrillation, biphasic waveforms will, in all likelihood, require lower energy settings than traditional machines.

AED/SAED

Perhaps no other area of resuscitative science has generated as much interest and controversy as automatic defibrillators. Over the past 15 years these devices have become smaller, cheaper, easier to maintain, and incredibly easy to use. Their widespread deployment promises great hope for victims of sudden cardiac arrest. Today, they are to be found in many airports, most commercial aircraft, and are typical equipment of first responders (e.g., park rangers, police and fire departments, lifeguards and ski patrol personnel). Increasingly they are also to be found in physician's offices, clinics, and hospitals. There are even versions designed for home use. Although it would be hard to argue the use of these devices by trained personnel, the issue of public access defibrillation (PAD) is more controversial. The cost of placing such a device "on every street corner" would be prohibitive, yet the liability of not having such a device immediately available is not trivial.[8] It is to be hoped that each community, in conjunction with the local EMS, providers would develop a plan for the rational placement of such devices along with appropriate training of personnel and ongoing assessment of need.

Pre-Arrest Interventions

It is imperative that health care professionals be able to identify potentially life-threatening situations, such as acute myocardial infarction and allergic reaction and be able to intervene, preferably *before* the patient arrests. Examples of this would include:

1. Acute coronary syndromes
2. Acute pulmonary edema, and/or hypotension (cardiogenic shock)
3. Symptomatic bradycardia
4. Unstable tachycardias
5. Acute ischemic stroke

In addition, the following pre-arrest conditions must be recognized and treated in a pro-active fashion.

1. Hypovolemia, secondary to blood loss or dehydration
2. Anaphylactic shock
3. Trauma
4. Sepsis
5. Respiratory failure

In each of the above situations, rapid intervention, which is beyond the scope of this chapter, must be taken in a methodical, rational manner so as to prevent the patient from arresting.

Post-Resuscitation Management

The patient who has return of spontaneous circulation (ROSC) is particularly vulnerable to sustaining an arrest again. The reasons for this are multiple: such patients are susceptible to reperfusion injury, cerebral edema, coagulopathy, and the effect of toxic free radicals. In addition, the underlying cause for the patient arresting may still be present and need further treatment after resuscitation. Although the care of the resuscitated patient is beyond the scope of this chapter, meticulous attention should be paid to the following:

1. Appropriate fluid and/or blood for resuscitation and hemodynamic support.
2. Continued support and assessment of adequacy of airway interventions. Particular attention should be paid to the oxygenation and pH of the patient.
3. Continued assessment and intervention(s) directed at the cause of arrest.
4. Attention to the temperature of the patient. There is intriguing evidence that cooling patients who have suffered cardiac arrest may improve outcome.[9]
5. Exploration to determine if electrolyte or other lab abnormality may have contributed to the patient's arrest.
6. Early antibiotic therapy for patients who are considered potentially suffering from meningitis or encephalitis.
7. For patients suffering from cardiac arrest, early consideration of either fibrinolytic therapy or angioplasty.
8. In patients, particularly if unconscious, early consideration of neurosurgical intervention.

Thrombolytics versus Primary PTCA

The introduction of thrombolytics for use in patients suffering from acute myocardial infarction revolutionized cardiac care. Prior to then, the clinician treating such a patient could do little but support the patient during their infarct. With the introduction of streptokinase and then tPA, the ability to open occluded coronary arteries and salvage myocardial tissue and function meant markedly reduced morbidity and mortality from such infarcts. Later, in the early 1990s, the technique of percutaneous coronary angioplasty (PTCA) was demonstrated to also be quite effective in opening occluded arteries and salvaging heart muscle. Today, the controversy surrounding the use of these two modalities concerns their appropriate place in treatment algorithms. The advantages and disadvantages of each are listed below:

Thrombolysis

Advantages:

1. Readily available in almost any emergency department.
2. Able to be rapidly administered to most patients suffering from a myocardial infarct.
3. Requires little or no additional staff, training, or equipment.

Disadvantages:

1. Is not usable in patients who have had recent surgery, trauma or have uncontrollable hypertension.
2. Carries the risk of hemorrhage, including the requirement for transfusion and the possibility of intracranial hemorrhage, often fatal.

Percutaneous Coronary Angioplasty

Advantages:

1. May improve coronary flow in comparison to thrombolytics.
2. Carries a much reduced risk of hemorrhage.
3. Can be used in patients who have contraindications to thrombolysis.

Disadvantages:

1. Requires additional, expensive personnel and equipment.
2. May not be available in all institutions and to all patients.

Over the past few years, it has become standard practice for most emergency physicians, working in community departments, without immediate access to a cardiac catheterization lab to treat the patients they see with acute myocardial infarct, to treat them with thrombolytics and consider transferring them to cardiac catheterization capable hospitals. Those physicians typically practicing in larger teaching facilities, more commonly referred their patients with acute myocardial infarcts to the on-call interventional cardiologist for primary PTCA. Recently, this practice has been called into question, with publication of at least one article demonstrating that transferring such a patient, even if it delayed catheterization for several hours, was beneficial to the patient.[10] Such a strategy has not yet been proven to be cost effective and the cost to the health care system of such an increase in cardiac catheterization has not been determined, yet alone, whether it can be afforded. This remains a very active area of research and controversy.

Future Directions

The science of cardiopulmonary resuscitation is literally growing daily. Some areas of research, promise for the future include:

- Wider availability of SAEDs.
- Hypothermia for patients suffering cardiac arrest.
- New medications, perhaps, including vasopressin for resuscitation and free radical scavengers to minimize cellular injury and death following cardiac arrest.
- Improvements in CPR including early access to it via public education and possibly new technologies to improve the CPR delivery.
- Improvements in oxygen delivery including new devices such as the oxylator.

The past 20 years have seen an explosive growth in our ability to treat the adult in cardiopulmonary arrest. Advances in treatment have saved thousands of people who would have died or would have been severely disabled with the use of earlier interventions, medications, and knowledge. It is hoped that the next 20 years of research and treatment of this disease will be equally rewarding.

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CHAPTER 2

Pediatric Resuscitation

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The resuscitation of infants and children is based upon the same fundamental principles as those used in adult patients. The "code" medications such as epinephrine, atropine, lidocaine, and normal saline are used, although they are dosed in a weight-based manner consistent with most pediatric drugs. The indications for interventions such as cardiopulmonary resuscitation and defibrillation are the same. The priorities of assessment—the "ABCs" of airway, breathing, and circulation—are identical.

It is essential, however, to appreciate the path that infants and children typically follow to cardiovascular decompensation and arrest, as it represents a departure from the "typical" cardiac arrest presentation in an adult patient. Adults commonly decompensate rapidly from a primary cardiac event such as acute myocardial infarction (AMI). In contrast, children typically follow an insidious and predictable path to cardiac arrest from origins of a primary respiratory (e.g., pneumonia, asthma), circulatory (e.g., dehydration, septic shock, or trauma), or at times metabolic instability (e.g., hypoglycemia). The assessment of the unstable child relies on an organized clinical evaluation of airway, breathing and circulation, looking for signs of inadequate oxygenation, ventilation, and perfusion. Using concrete physical exam findings such as capillary refill time and assessing mental status are essential. These qualitative assessments are as important as the quantitative data from vital signs, which can be falsely reassuring. Blood pressures in the pediatric patient can remain within the normal range in critically ill children until decompensated cardiopulmonary failure has occurred. Physical signs of hypoperfusion should always be considered an ominous sign of imminent arrest in infants and children. By aggressively identifying and treating signs and symptoms of compensated respiratory or circulatory impairment, it is frequently possible to prevent cardiac arrest.

Children and infants can remain in a compensated state with an evolving respiratory or circulatory disorder for prolonged periods of time. However, unrecognized and untreated respiratory distress or compensated shock can progress to a less stable decompensated state of respiratory failure or decompensated shock (**FIGURE 2.1**). This is the "golden window" when it is critical to identify and treat the sick or injured child in order to prevent subsequent decompensation, cardiopulmonary failure, and arrest.

A practical example of this model would be a child who develops severe wheezing from asthma and does not have access to treatment. Because of the decreased ability to ventilate, the child would move quickly into *compensated* respiratory distress. She would likely have tachypnea and a normal to high blood pressure. As the situation deteriorates, her tachypnea would become extreme, perioral cyanosis may develop, and her blood pressure would remain normal to high. She will pass into the *decompensated phase* of respiratory failure, as she becomes more acidotic, hypoxic, and hypercarbic. She is soon unable to maintain an adequate blood pressure, and becomes agitated and incoherent. After this she slows her respiratory rate, becomes somnolent, and then loses consciousness. Moments later she becomes apneic and bradycardic, and cardiac arrest occurs follows shortly.

This example illustrates the importance of early recognition of respiratory or circulatory distress (compensated states). With a treatable disease such as asthma, there are typically several opportunities for early intervention that can prevent an unfortunate outcome. The first would be the parent or patient's observation that the child needed treatment with her bronchodilator medication. The second is when she presents to the EMS provider or a clinician who recognizes that her worsening distress is a sign of impending trouble, even with a stable heart rate and blood pressure. The opportunity still exists to reverse her pathology with a bronchodilator and prevent further complications. If she worsens and presents to an emergency department in compensated respiratory distress, the ongoing tachypnea and respiratory distress should prompt rapid intervention with inhaled or parenteral bronchodilators, airway support, oxygen, fluid, and steroid medication. Once the patient progresses to cardiopulmonary failure (with global deficits in oxygenation, ventilation and perfusion; and presents with cyanosis, ineffective respiratory effort and bradycardia), aggressive and immediate resuscitation with assisted ventilation, oxygenation, vascular access, and resuscitation are needed to prevent cardiac arrest.

Young patients require a rapid yet organized and thorough assessment to detect the often subtle presentation

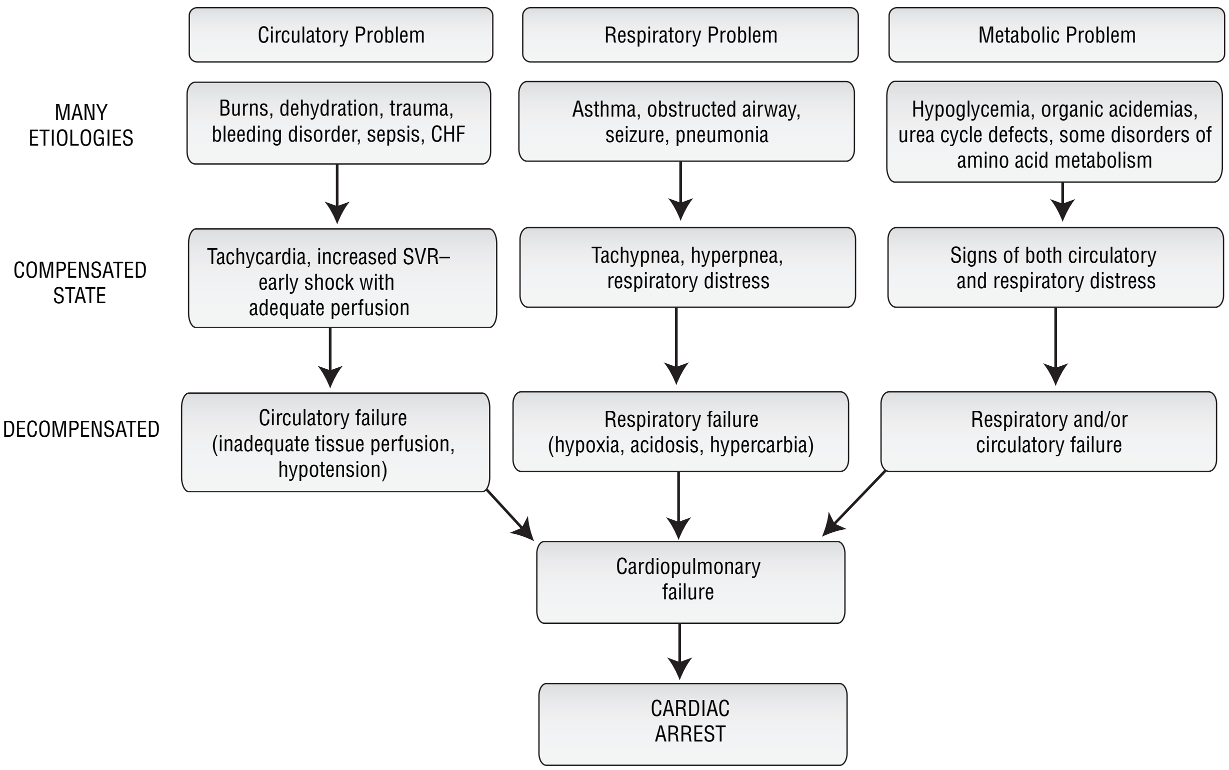

FIGURE 2.1 Cardiovascular decompensation can result from multiple problems and follows a common pathway.

of circulatory or respiratory distress and failure. Special training classes such as Pediatric Advanced Life Support (PALS), Advanced Pediatric Life Support (APLS), and the Neonatal Resuscitation Program (NRP) are useful for learning these specialized assessment skills and resuscitation strategies that are unique to infants and young children. There are also tools that can reduce some of the stress inherent in caring for a child who is sick or injured, such as a height-based weight estimation tape. An organized rapid cardiovascular assessment should help with the search for reversible disease, and it reflects the ubiquitous "ABC" (airway, breathing, circulation) approach of emergency medicine. Many courses will add the category of "first impression" or "appearance" to this first impression.

A rapid systemic cardiopulmonary assessment in a child at risk for decompensation begins with the airway. It is vital to rapidly identify and treat airway obstruction. In the setting of a functional obstruction from the tongue or secretions, this may be quickly done with positioning, suction and airway adjuncts. Remember that infants and young children have a large occiput and will typically benefit from a towel pad under the shoulders to help open the airway (**FIGURE 2.2**). When assessing the breathing, it is important to assess the respiratory rate over a minute as well as the qualitative aspects of the exam such as wheezing, stridor, chest expansion, symmetry of breath sounds, and the effort required to move air. Finally, assess the child's skin color for cyanosis or pallor. Imminent threats such as wheezing, pneumothorax or foreign body aspiration should be identified and treatment begun immediately. Administer oxygen (100% O_2 via nonrebreather mask) to any potentially unstable infant or child.

The cardiovascular assessment also has quantitative and qualitative components. Measurement of the heart rate (HR) and blood pressure (BP) (**Table 2.1**) can promptly identify the presence of instability, but reassuring numbers do not rule out serious pathology. Remember that the hemodynamic response to hypovolemia does not include a fall in BP until approximately half of the circulating vol-

FIGURE 2.2 Use a shoulder roll or folded towel to position the airway of the infant and young child.

Table 2.1

Vital sign normal values in pediatric patients

Age	Mean Weight (kg)	Minimum Systolic BP	Normal Heart Rate	Normal Respiratory Rate
Premature	<2.5	40	120–170	40–60
Term	3.5	60	100–170	40–60
3 months	6	60	100–170	30–50
6 months	8	60	100–170	30–50
1 year	10	62	100–170	30–40
2 years	13	74	100–160	20–30
4 years	15	78	80–130	20
6 years	20	82	70–115	16
8 years	25	86	70–110	16
10 years	30	90	60–105	16
12 years	40	94	60–100	16

ume has been depleted. The same graph demonstrates the usefulness of assessing for signs of cardiac output and increased vascular resistance. These are much more useful indices of shock than BP alone. Assessment of the skin may show coolness, mottling, and a prolonged capillary refill time. Check these variables on the skin of the head or trunk for comparison with the extremities, especially if the child is in a cold environment where some vasoconstriction of the extremities is normal. Determining the peripheral pulse is another way of estimating cardiac output, as thready or absent distal pulses can be an indication of ongoing shock. Assessing end organ function is also useful. The central nervous system is susceptible to the effect of shock, so altered mental status—agitation or lethargy—is a serious sign. Monitoring urine output can be an important tool is useful in determining end organ perfusion in the setting of shock, as well as gauging the effectiveness of fluid resuscitation.

Metabolic instability can also contribute to or cause cardiovascular decompensation and arrest from processes such as hypoglycemia and acidosis. Euglycemia is essential for normal cardiac function, especially in the newborn and young infants. Glycogen storage capacity is normally lower in these very young patients, making them at a higher risk for hypoglycemia. This is especially true when a child is ill and may not have optimum oral intake. There are numerous inborn errors of metabolism, such as the organic acidemias, urea cycle defects, and amino acid metabolic disorders that can present with life-threatening acidosis or the accumulation of toxic metabolites. These can lead to cardiovascular instability through a cellular process.

Infants can present an especially difficult challenge for several reasons. Younger children have a higher metabolic rate and therefore a greater subsequent oxygen requirement. This lowers their ability to tolerate hypoxia, something seen clearly in premature infants, who may desaturate within moments and become bradycardic and asystolic very rapidly after airway obstruction. The cardiopulmonary assessment and the onset of interventions should occur via a team approach in a critically ill patient. It is not appropriate to delay interventions to wait for laboratory results or radiography. Respiratory distress should be treated with oxygen, suction, and positioning, with airway interventions individualized based on the specific problem. This may require utilizing measures such as bronchodilators, obstructed airway maneuvers, or needle decompression of the chest. It is important to continually reassess the airway and breathing effort after any intervention, as rapid changes are common. If necessary, assistance through the use of the bag-valve mask (BVM) should be initiated. Most children and infants can be easily ventilated with the BVM, but it is a skill that must be frequently practiced to be effective. Intubation of children in actual or imminent respiratory failure should not be the first line treatment of respiratory distress or failure. BVM airway support is faster and very effective, allowing time to adequately prepare for a successful intubation. If the airway is difficult to secure with intubation or BVM, consider the use of the laryngeal airway mask (LMA), a device that has a high success rate for first time placement, but provides little protection of the airway from stomach contents.

A similar approach should be occurring with circulatory failure. The child with compensated shock will have tachycardia and possibly a diminished capillary refill time. Fluid resuscitation and hemorrhage control is the first line of therapy, using isotonic fluid (normal saline) (NS) or a Lactated Ringer's solution (LR). Hypotonic solutions such as 5% dextrose (D5W) for acute volume replacement are not indicated. Administration of rapidly infused NS or LR fluid boluses in increments of 20 mL/kg should occur with frequent reassessment until the vital signs and exam improve. Consider the possibility of congestive heart failure/congenital heart disease, third spacing, hidden bleeding or a surgical emergency if the patient worsens or does not improve after multiple fluid challenges have been administered. The use of broad-spectrum antibiotics or prostaglandins is indicated if sepsis or congenital cardiac disease is a possibility. Studies such as lumbar puncture should be deferred until first-line resuscitation is completed. Vasopressors are not first line treatment for patients in circulatory failure. They should be considered after adequate fluid resuscitation especially in the setting of distributive shock (sepsis, anaphylaxis) or congestive heart failure.

It has been described that primary cardiac disorders are a less likely cause for cardiovascular failure children outside of the neonatal age group. It is not uncommon, however, for arrhythmias such as ventricular fibrillation or ventricular tachycardia to present in an unstable child who has decompensated for other reasons. The indications for cardioversion and defibrillation are the same for infants and children as in adults. The use of the now ubiquitous automated external defibrillator (AED) is appropriate for children over 1 year of age, even if special energy modulating pads are not available.[1] It is expected that AED use in children under 1 year old may be indicated in the future.

Infants and children are efficient at maintaining a compensated state with most circulatory or respiratory insults. Conversely, once a child decompensates and develops cardiopulmonary failure, there is little time to reverse the process before cardiac arrest ensues. It is vital to have the skill to recognize the signs and symptoms of respiratory distress and circulatory failure and intervene as early as possible.

The child who ends up in or presents with cardiopulmonary arrest is treated in a similiar fashion to the adult. The ABC survey is performed, ventilation is secured (BVM followed by intubation), and prompt defibrillation at pediatric dosages is administered if it is indicated by ventricular tachycardia or fibrillation. The administration of ACLS medications is essentially the same as for adults, but it is necessary to know or estimate the patient's weight in kilograms for proper dosing. The American Heart Association 2000 guidelines contain some important updates in pediatric resuscitation:

1. Standard dose epinephrine has simplified the treatment of asystole.
2. The cause of PEA should be aggressively sought as resuscitation is ongoing (hypoxia, hypothermia, hyper/hypokalemia, hypovolemia, toxin, thromboembolus, tension pneumothorax, tamponade).
3. Amiodarone is an optional replacement for lidocaine as an antiarrhythmic for ventricular fibrillation or pulseless ventricular tachycardia.
4. Bretyllium is no longer recommended for pediatric use.

Because pediatric cardiac arrest may or may not be a primary cardiac event, it is important to search for reversible causes of airway and circulatory insult, such as pneumothorax, hemorrhage, seizure or head injury. Hypoglycemia and hypothermia are causes and complications of arrest in infants. They should be detected and treated during resuscitation. Once the infant has regained a perfusing rhythm, both of these parameters should be monitored closely. The larger surface-to-body ratio of children makes them especially vulnerable to hypothermia before and after they arrive at the hospital and needs to be addressed during and after resuscitation maneuvers are made. Lastly, consider a toxicologic insult (including alcohol) that could have caused the patient to decompensate, especially in the toddler or adolescent patient.

As in adult medicine, the science of pediatric resuscitation is constantly evolving. Some of it is specific to the pre-hospital environment, but much of it applies to both pre-hospital and in-house resuscitation. There are several topics that are being evaluated currently, many of which are extensions from adult resuscitation research, included here for informative purposes:

- Similar to adult patients, there is a growing support of the judicious use of IV crystalloid resuscitation in the pre-hospital environment rather than the aggressive use of IV boluses. This is especially true in patients injured traumatically. In contrast, there is a clear role for the use of prompt and repetitive fluid boluses in the resuscitation of pediatric patients with septic shock.
- During cardiopulmonary resuscitation (CPR), there is some controversy over the adequacy of coronary perfusion pressure that is achieved by a 5:1 ratio of compressions to ventilations. Alternatives being explored are the classic adult CPR radio of 15:2, which demonstrates an improved coronary perfusion pressure during compression for the latter ⅔ of the compression phase. It is thought that it may take a series of approximately 5 compressions to generate forward coronary perfusion pressure with CPR. Other alternatives to traditional CPR are also being studied, such as interposed abdominal compressions to increase coronary and cerebral perfusion.
- Aufderheide, Sigurdsson et al published in 2004[2] that there are indications that the over-ventilation of patients by clinicians commonly seen in resuscitation may be contributing to the poor survival rates after cardiac arrest. This is likely due to an increase in intrathoracic pressure and a resultant drop in coronary perfusion pressure from a respiratory rate that is too high.
- Delaying defibrillation for several minutes of CPR was noted to result in a statistically increased survival rate in out-of-hospital ventricular fibrillation arrests according to Wik et al.[3] This is much more applicable to the adult population, where a primary cardiac arrhythmia is more likely to result in cardiovascular failure.
- In 2003, Gausche et al.[4] showed that in the Los Angeles and Orange County, California pre-hospital care system, the use of bag-valve mask resuscitation versus endotracheal intubation by paramedics on pediatric patients demonstrated no difference in outcome. At the same time, it was noted that patients who were intubated had longer scene times by 2 to 3 minutes and had an 8% rate of unrecognized tube displacement or misplacement. Based on this study, pediatric intubation protocols were modified in this service area. There are questions as to the generalizability of this extensive study to other pre-hospital systems or the emergency department, but it certainly emphasizes the role of excellent bag-valve mask skills in pediatric clinicians.
- The use of cuffed versus uncuffed endotracheal tubes in children under 8 years old is being considered. The PALS guidelines recommend uncuffed tubes in this age group for ease of placement, the presence of anatomic structure that obviates the need for a cuff,

risk of the cuff's damaging the airway, and the fact that the cuff reduces the inner diameter of the tube slightly. Proponents of cuffed tubes state that they can reduce air leak and prevent the need for tube changes as frequently. It is likely that end tidal carbon dioxide monitoring is more accurate with a cuffed tube.

- The use of vasopressin, as an alternative to epinephrine in pediatric cardiac arrest, is controversial. There is evidence that there may be a worse outcome in some animal models. The American Heart Association 2000 Guidelines state that "data is insufficient to allow a recommendation of vasopressin in children with cardiac arrest." Supporting the use of vasopressin, there have been several animal trials and a small case series, which indicate that its use may be beneficial. Studies in the adult realm have demonstrated improved outcomes for patients with asystole, but it was a subgroup analysis on a larger study that showed no difference between the use of epinephrine and vasopressin.[5]
- It is becoming evident that the use of high-dose (0.1 mg/kg) epinephrine in pediatric cardiac arrest may be detrimental. Perondi et al.[6] noted that in children with in-hospital cardiac arrest, there was a similar return of spontaneous circulation that was equivalent in the high- and low-dose groups. However, no patients receiving high-dose epinephrine survived to discharge versus 12% in the low-dose (0.01 mg/kg) group.

Skills and assessment classes such as PALS will help the new or experienced provider feel more confident with infant and pediatric assessment and resuscitation. The same can be said for frequent practice of these skills using full-context "mock code" scenarios in the workplace. This is especially important for trainees who need to feel comfortable with basic resuscitation skills prior to working without supervision.

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