Cardiovascular disease (CVD) is the leading cause of death in the United States. Mortality data show that CVD as the underlying cause of death accounts for 35.3% of all deaths in the United States. There is a wide variation in the reported incidence and outcome of out-of-hospital cardiac arrest (OHCA). Cardiac arrest is defined as cessation of cardiac mechanical activity with absence of signs of circulation. The estimated number of OHCA cases is approximately 300,000 per year in the United States. The median reported survival to hospital discharge after OHCA with any first reported rhythm is 7.9%. Two landmark studies published together in 2002 demonstrated that the use of therapeutic hypothermia after cardiac arrest decreased mortality and improved neurological outcome. Based on these studies, the International Liaison Committee on Resuscitation and the American Heart Association recommended the use of therapeutic hypothermia after cardiac arrest. Therapeutic hypothermia is defined as a controlled lowering of core body temperature to 32°C or up to 34°C. This temperature goal represents the optimal balance between clinical effect and cardiovascular toxicity. Therapeutic hypothermia requires resources to implement—including device, close nursing care, and monitoring. It is important to select patients who have potential for benefit from this technique, which is a limited resource and carries potential complications. A collaborative team approach involving physicians and nurses is critical for successful development and implementation of this kind of protocol.

In this chapter we describe our pathway for the comprehensive management of OHCA survivors. This pathway is limited to OHCA and does not include inhospital arrest.

**PATHWAY DESCRIPTION**

The pathway is divided into three steps as shown in Figure 20.1.

**Step I.** From the field through the emergency department (ED) into the cardiac catheterization laboratory and to the critical care unit.

**Step II.** Induced invasive hypothermia protocol in the critical care unit.

**Step III.** The management following the rewarming phase including the recommendation for out-of-hospital therapy and the ethical decision to define goals of care.

**STEP I**

*Presentation to the emergency department, proceeding to the cardiac catheterization laboratory and to the critical care unit.* Upon arrival of a survivor of OHCA to the ED, the initial assessment includes vital signs, physical examination, and neurologic examination with Glasgow coma score. Immediate 12-lead EKG is obtained and laboratory testing performed. Initial laboratory testing includes complete blood count (CBC) with differential, basic metabolic panel, cardiac marker (troponin, CPK, CPK-MB), B-type natriuretic peptide (BNP), prothrombin time (PT), partial thromboplastin time (PTT), international normalized ratio (INR), lipid profile, phosphorus, calcium, magnesium, lactate, ß-HCG (for women), TSH, and toxicology screening. We recommend a head CT without contrast only if it is clinically indicated and will not delay transfer to the cardiac catheterization laboratory.

The patient is stabilized in the ED where antiarrhythmic and vasopressor therapy may be administered, in addition to ventilator support. The ED physician receives the emergency medical services (EMS) report of the primary rhythm and duration of cardiopulmonary resuscitation (CPR). This reported arrhythmia is the key decision point in our pathway.

The patient is stabilized in the ED where antiarrhythmic and vasopressor therapy may be administered, in addition to ventilator support. The ED physician receives the emergency medical services (EMS) report of the primary rhythm and duration of cardiopulmonary resuscitation (CPR). This reported arrhythmia is the key decision point in our pathway.

The prognostically important distinction is between patients with documented ventricular fibrillation (VF) or sustained ventricular tachycardia (VT) who had a restoration of spontaneous circulation (ROSC) in <30 minutes and patients with reported asystole or pulseless electrical activity (PEA) (Figure 20.3).

1. If the initial rhythm was VF or VT with an ROSC of ≤30 minutes the cardiac arrest team is activated, and the patient will proceed to the cardiac catheterization laboratory (Figure 20.4).
2. If the initial reported arrhythmia was PEA or asystole, the next step will depend on the EKG performed in the ED (Figure 20.4). If the EKG performed in ED is suggestive of priority ACS (including ST elevation MI, left bundle branch block, or acute posterior wall MI), the MI team should be activated, and the care is similar to those patients with reported VF or VT arrest.

3. If priority EKG findings are not seen but the etiology of the arrest is most likely owing to primary cardiac disease, the cardiology fellow will admit the patient to the cardiac care unit. We recommend an emergency echocardiogram.

4. If the etiology is likely noncardiac, the patient will be admitted to the medical intensive care unit.
The cardiac arrest team includes the following 10 people.

The traditional (acute coronary syndrome) ACS-MI team comprises the following members:

1. Interventional cardiologist on-call—the team leader
2. CCU director
3. Cardiology fellow on-call
4. Interventional cardiology fellow on-call
5. Cath lab nurse on-call
6. Cath lab technician on-call
7. CCU nurse manager on-call
8. The neurologist on-call
9. The critical care attending on-call
10. The medical resident screener

In addition, the following personnel form the team:

8. The neurologist on-call
9. The critical care attending on-call
10. The medical resident screener

The MI team is activated by a single page to the central call center by the ED physician.

Steps in the emergency department.

1. Decision to initiate induced hypothermia is made jointly by the ED physician and the cardiology or critical care physician. It is very important to review the hospital center’s inclusion and exclusion criteria and decide whether the patient is a candidate for the therapeutic hypothermia protocol (Figure 20.5).
2. The physician places an order to initiate hypothermia protocol.
3. Noninvasive hypothermia is initiated by the administration of iced saline in ED.

Our goal is to transfer the patient to the PCI center as soon as possible with a target door-to-balloon time of <90 minutes.

The management of the patient at this point is according to our Priority risk, Advanced risk, Intermediate risk, and Negative/low risk.

Induced hypothermia protocol

**Inclusion:**
1. Age >18 years
2. Coma at time of cooling
   - Not following command
   - No purposeful movement
   - Reflex and pathological/posturing movements are permissible

**Exclusion:**
1. Patient awake and follows command
2. Known terminal illness/DNR
3. Refractory shock despite vasopressors
4. Pregnancy (relative contraindication)
5. Multiorgan failure

Figure 20.5. Inclusions and exclusions criteria for patients who are candidate for the therapeutic hypothermia protocol.
Phase 1: Invasive cooling phase for the first 24 hours. In the two landmark studies published in 2002, Bernard et al. cooled patients to 33°C for 12 hours, and the HACA trial cooled patients to 32°C and up to 34°C for 24 hours.

We recommend 24 hours of the cooling therapy at a temperature goal of 33°C.

Endovascular catheters are an effective method of inducing therapeutic hypothermia. The catheters are usually inserted into the inferior vena cava through the femoral vein.

Continuous core temperature monitoring is required and generally accomplished using a temperature probe in the bladder (urinary catheter) or the rectum.

Monitoring of clinical condition and potential complications during the invasive cooling phase.

As there are many physiologic effects of hypothermia, we recommend continuous monitoring and hourly documentation of vital signs; core temperature; cardiac rhythm; hemodynamic, respiratory, neurology status; and urine output. Common hemodynamic changes observed with cooling include hypertension, decreased cardiac output, and increased systemic vascular resistance. The hypertension and the increased systemic vascular resistance are believed to result from the cold-induced vasoconstriction.

Serum electrolyte imbalance is common during the cooling phase and results from the cooling-induced intracellular shifts of potassium, magnesium, calcium, and phosphate resulting in low levels of all these electrolytes. During the rewarming phase these electrolytes shift back to the extracellular space.

Our protocol therefore recommends measurements of the basic metabolic panel every 4 hours for a total of 48 hours, measuring electrolytes (calcium, magnesium, and phosphate) PT, PTT, and INR, and a CBC every 12 hours up to 48 hours.

Additional possible side effects of cooling to be monitored include the following:

1. Coagulopathy. Coagulopathy is generally not significant with careful temperature monitoring and avoiding temperature of <33°C. If active bleeding occurs during the cooling phase, evaluation of coagulation factors and platelets should be performed and deficiencies corrected.

2. Hyperglycemia. Hypothermia suppresses insulin release and causes insulin resistance. Our insulin infusion protocol for the management of hyperglycemia in critical care unit is used.

3. Infection. Infection is usually multifactorial including emergency intubation and intravenous catheter insertion and aspiration pneumonia at the time of arrest.

Furthermore, the hypothermia itself can suppress white blood cell production and impairs neutrophil and macrophage function. All measures to reduce ventilator associated pneumonia are employed including elevating the head of the bed.


Phase 2: Rewarming phase. After 24 hours of the target temperature, the rewarming phase starts.

Controlled rewarming is a very important phase of this protocol.

Rewarming should be slow; we recommend a rate of 0.25°C per hour; therefore it typically requires 16 hours to rewarm to 37°C.

Potential complications during the rewarming phase include the following:

1. Hypotension—owing to peripheral vasodilatation during the rewarming phase.

2. Electrolyte imbalance—increased levels of potassium, magnesium, calcium, and phosphate owing to intracellular shifting of these ions back to the serum during the rewarming phase.

Phase 3: Maintenance of normothermia phase. The maintenance phase is the last phase of the therapeutic hypothermia protocol.

Normothermia maintenance takes effect when the patient’s temperature reaches 37°C.

We recommend continuation of the cooling device to maintain a temperature of 37°C and avoid fever that can potentially worsen a cerebral injury.

STEP III

The management following hypothermia and rewarming depends on the neurologic prognosis (Figure 20.7).
At least 72 hours postcardiac arrest, the neurologic examination is performed by the neurology team. The neurologic examination may be affected by the hypothermia protocol, including requirements for sedation and therapeutic paralysis, so that the formulation of a neurologic prognosis may be delayed. The pathway for the patients will be divided based on whether the patient has a favorable neurologic prognosis or an unfavorable neurologic prognosis. An unfavorable neurologic prognosis would be defined as expectation for a persistent coma or vegetative state, or severe disability.

If the prognosis appears unfavorable, we recommend activating the ethics committee to meet with the family and clinicians to define the goals of care. From our experience, in most instances, life support is limited or withdrawn in such patients.

If the neurological prognosis appears favorable, then the key question regarding further therapy is based on whether the cardiac arrest was because of MI.

If there is no evidence of acute MI (negative cardiac markers) then we recommend electrophysiology service consultation for consideration of implantable cardioverter defibrillator (ICD) placement and treatment of heart failure based on our heart failure pathway as indicated.

If acute MI is confirmed by positive cardiac markers we advise care based on the LV ejection fraction (LVEF) as it is defined by echocardiography or other imaging modalities. If LVEF ≤35% we recommend activation of the ESCAPE pathway for sudden cardiac death prevention and to consider ICD placement if EF ≤35% at 40 days post-MI. Also, we recommend managing heart failure according to our heart failure pathway.

If EF >35% we recommend following our PAIN pathway for the management of ACS including the following:

- Lifestyle modification
- Cardiac rehabilitation
- Secondary prevention medication (aspirin, clopidogrel or prasugrel, β-blocker, high dose statin, ACE inhibitor/ARB)

**REFERENCES**

PATIENT AND FAMILY INFORMATION FOR: Survivors of Out-of-Hospital Cardiac Arrest, Including Therapeutic Hypothermia

Heart disease is the leading cause of death in the United States, accounting for one-third of all deaths in the United States. Cardiac arrest is sudden loss of heart function in a person who may or may not have been previously diagnosed with heart disease. When cardiac arrest occurs outside the hospital, it is referred to as Out of Hospital Cardiac Arrest (OHCA). The estimated number of OHCA cases is approximately 300,000 per year in the United States. Cardiac arrest occurs when the electrical system of the heart malfunctions leading to abnormal heart rhythms called arrhythmias. The two commonest arrhythmias that cause cardiac arrest are ventricular fibrillation (VF) and ventricular tachycardia (VT). In both VF and VT, the lower chambers of the heart beat chaotically and cannot effectively pump blood to the organs including, and most important, the brain. Without blood flow to the brain, death will occur within minutes after the heart stops pumping. Cardiac arrest may be reversed if CPR is initiated immediately, and a device called a defibrillator is used to electrically shock the heart back to a normal rhythm. Even when cardiac arrest is reversed, and a normal heart rhythm is restored, many individuals who suffer cardiac arrest are left with irreversible brain damage. Less than 1 in 10 patients who suffer OHCA survive to be discharged from the hospital, and those who survive are often left with considerable brain damage and permanent disability. Effective CPR by either a bystander or a trained medical professional and early treatment with a defibrillator can minimize the amount of brain damage and increase the chance of survival.

Two important trials, published together in 2002, demonstrated that the use of a technique called “therapeutic hypothermia” after cardiac arrest can minimize brain damage and increase the likelihood of survival without significant disability. Based on these studies, the International Liaison Committee on Resuscitation and the American Heart Association recommend the use of therapeutic hypothermia after cardiac arrest.

Therapeutic hypothermia involves cooling the patient’s body temperature from normal temperature (approximately 37°C, or 98.6°F) to a temperature between 32°C and 34°C (89.6°F and 93.2°F). This technique minimizes damage to brain cells by limiting a complicated inflammatory process that occurs in the brain after cardiac arrest. Because there are risks involved with therapeutic hypothermia, patients must be carefully selected to include only those in whom the benefit outweighs the risk. A collaborative team approach involving physicians and nurses is critical for successful implementation of this technique.

In this chapter, we describe our pathway for the comprehensive management of survivors of OHCA. This pathway is limited to OHCA and does not include in-hospital cardiac arrest.

PATHWAY DESCRIPTION

The Pathway is divided into three steps.

Step I. Initial assessment and stabilization of the patient in the Emergency Department (ED). A plan of care is decided upon by a designated team of physicians, including whether to perform cardiac catheterization and whether to initiate therapeutic hypothermia.

Step II. Management of the patient in the critical care unit including implementation of the hypothermia protocol.

Step III. Management of the patient following completion of the hypothermia protocol. This begins with an evaluation of brain function and the likelihood of recovery, followed by recommendations for further therapy and, if necessary, evaluation by the ethics committee to assist in defining goals of care.

STEP I

Initial evaluation and treatment of a survivor of out of hospital cardiac arrest. The initial evaluation of a survivor of OHCA upon arrival to the ED includes vital signs, physical examination, and a standard assessment of brain function called the Glasgow coma score. An EKG is obtained immediately and laboratory testing is performed. Initial laboratory testing includes basic tests of kidney, liver, and thyroid function as well as blood count and chemical markers of heart muscle damage called cardiac biomarkers. If there is a suspicion of a stroke or bleeding in the brain, a special type of X-ray of the head called a CT scan may be performed.

Although the initial evaluation is ongoing, steps are taken to stabilize the patient’s condition. Virtually all patients who suffer a cardiac arrest are temporarily unable to breathe on their own and require support with a mechanical ventilator.
Many will require medications to maintain a normal blood pressure and to prevent any further abnormal heart rhythms. Once the patient’s condition is stable, a decision is made regarding therapeutic hypothermia. If the patient meets criteria for entry in our hypothermia protocol, then therapeutic hypothermia is initiated in the ED by infusion of cold saline through an IV catheter. The criteria for entry into the hypothermia protocol will be discussed in detail in the next section. These criteria are designed to ensure that only patients in whom the benefits of the therapy outweigh the risks are included in the protocol. The decision whether to initiate therapeutic hypothermia is made jointly by the ED physician and the cardiology or critical care physician.

Cardiac arrest may occur as a primary abnormality of the heart’s electrical system but more often occurs in the setting of a heart attack. A heart attack is caused by a severe narrowing or complete blockage of one or more of the major coronary arteries—the blood vessels that deliver blood to the heart. In the case of a cardiac arrest that is caused by a heart attack, the patient must undergo an emergent procedure called a cardiac catheterization and possible angioplasty to open the blocked vessel.

Therefore, if the initial cardiac arrest was caused by VF or VT, or the EKG is suggestive of a heart attack, the patient is transferred immediately to the cardiac catheterization laboratory, where a cardiac catheterization is performed. Explanations of the catheterization procedure, angioplasty, and the management of a heart attack are provided in detail in Chapters 1 to 4. After completion of the cardiac catheterization, the patient is transferred to the cardiac care unit (CCU).

If neither of above criteria is met, the patient is transferred directly to the CCU where an emergency echocardiogram is performed. An echocardiogram is an ultrasound of the heart that provides the physician with essential information regarding the structure and function of the heart muscle and heart valves. This is described in more detail in Chapter 5.

If the cardiac arrest is deemed not to be a primary malfunction of the heart but a consequence of serious medical illness, the patient is transferred to the medical intensive care unit for further care.

In the critical care unit therapeutic hypothermia is continued with initiation of the invasive hypothermia protocol.

STEP II

Induced invasive therapeutic hypothermia protocol in the critical care unit. The induced invasive hypothermia protocol begins when the patient arrives in the cardiac or medical critical care unit. The term invasive simply refers to the method of cooling that involves placement of a specialized catheter in a large vein in the leg called the femoral vein. This technique will be discussed in more detail later in this chapter. The physicians review the case and confirm that therapeutic hypothermia is appropriate. We recommend therapeutic hypothermia for patients older than 18 years of age who have suffered a cardiac arrest and remain in a coma. A coma is a deep state of unconsciousness. Patients who are in a coma cannot be awakened, do not respond normally to stimulation such as light, sound, and pain, and do not make any voluntary movements. Patients excluded from the hypothermia protocol include those who are awake, have a severe or a terminal medical illness, or who suffered a prolonged period from the onset of cardiac arrest until the heart could be shocked back to a normal rhythm.

The hypothermia protocol is divided into three phases.

Phase 1: Invasive cooling phase for the first 24 hours
Phase 2: Rewarming phase and
Phase 3: Maintenance phase

Phase 1: Invasive cooling phase for the first 24 hours. Controlled cooling of the core body temperature is achieved by means of a catheter that is placed in the femoral vein. The catheter is attached to a specialized cooling system that is designed to continuously measure core body temperature and adjust the rate of cooling accordingly. This controlled method of cooling has proven to be safe and effective. Based on the available evidence from the two trials mentioned earlier we recommend cooling the patient to 33°C (91.4°F). At this temperature the patient receives the protective benefit of hypothermia with minimal side effects.

Patient monitoring and potential side effects of the hypothermia protocol.

Although major side effects are rare, there are a number of potential complications that can occur in patients being treated with therapeutic hypothermia. The most common effects of hypothermia include the following:

1. Elevated blood pressure. Cooling can cause increased blood pressure and decreased heart function. For this reason we recommend continuous monitoring and hourly documentation of many important clinical markers including, but not limited to, temperature, heart rhythm, blood pressure, and heart rate.

2. Infection. Cooling can weaken immune system function by interfering with normal white blood cell production and function. This can lead to an increased risk of infection. The risk of infection is further increased by the many emergent procedures that must be performed in any patient who suffers a cardiac arrest. Therefore, as part of our protocol, blood cultures and white blood cell counts are checked to help identify early signs of infection. Preventive measures are taken to minimize the risk of infection and antibiotics are administered when necessary.

3. Blood electrolytes abnormalities. Cooling can cause abnormalities of blood electrolytes especially potassium and magnesium. During the hypothermia protocol electrolyte levels are monitored every 4 hours and imbalances are corrected appropriately.

4. Elevated blood sugar. Cooling can cause abnormally elevated blood sugars. We control blood sugar levels using an insulin infusion protocol that we have developed for the management of elevated blood sugar in the critical care unit. Our protocol is described in detail in Chapter 32.

5. Shivering. Shivering can increase body temperature and interfere with cooling. Our protocol aims to prevent shivering by administration of medications that temporarily
paralyze muscle function. The patient is well sedated with medications and will not experience any discomfort from the muscle paralysis.

**Phase 2: Rewarming phase.** After keeping the patient at a body temperature of 33°C (91.4°F) for 24 hours we begin rewarming. To ensure patient safety we rewarm the patient in a controlled fashion at a slow rate of 0.25°C per hour. It should take 16 hours to raise the patient’s body temperature back to normal (37°C or 98.6°F). The commonest side effects of rewarming include a drop in blood pressure and imbalances of blood electrolytes. The patient is carefully monitored during the rewarming phase to avoid these complications.

**Phase 3: Maintenance of normal body temperature.** The maintenance phase is the last stage of our hypothermia protocol. It is common for patients to develop fever after suffering a cardiac arrest. This can be owing to infection, medications, or damage to the part of the brain that regulates body temperature. Increased body temperature during the recovery period after a cardiac arrest can be particularly dangerous as it may worsen brain damage. We recommend using the cooling device to maintain a normal body temperature for at least an additional 24 hours after the rewarming stage is complete.

**STEP III**

*Neurologic evaluation to determine long-term prognosis after completion of the hypothermia protocol.* Once the hypothermia protocol is complete, it is important to perform a thorough neurologic evaluation—an evaluation of the patient’s brain function to determine the likelihood of recovery. This evaluation is performed by a neurologist, a physician who specializes in brain function, and is generally performed approximately 72 hours after the cardiac arrest. Because some of the medications administered during the hypothermia protocol may interfere with the neurologic evaluation, it is often necessary to repeat the evaluation at a later time before making a final decision regarding prognosis.

If the brain damage is severe and it is likely that the patient will either remain in a coma or be left with permanent, severe disability we recommend involving the hospital’s ethics committee. The Ethics Committee will meet with the physicians caring for the patient and the patient’s family members to help decide on a plan of care. In this situation life support is often withdrawn, and aggressive measures are often limited, to maximize patient comfort.

If the prognosis is favorable and the patient is likely to recover without significant disability the next step is to determine whether the patient qualifies for an implantable cardioverter-defibrillator (ICD). An ICD is a small device similar in size to a pacemaker that is implanted under the skin during a minor surgical procedure. The ICD is programmed to recognize abnormal heart rhythms that can lead to cardiac arrest and restore the heart rhythm to normal by delivering a small electric shock. ICDs have been proven to save lives in patients who are at risk for cardiac arrest.

The decision whether to implant an ICD is complicated and will be made in agreement with an electrophysiologist, a cardiologist who specializes in pacemakers and abnormal heart rhythms. The decision depends largely on whether the patient is considered to be at risk for another cardiac arrest. The electrophysiologist will consider the cause of the initial cardiac arrest as well as the heart muscle function as measured by echocardiogram in assessing the patient’s risk of another cardiac arrest.

It is common for patients who recover from a cardiac arrest, especially when the cardiac arrest was caused by a heart attack, to be left with a weak heart that can no longer pump blood at full capacity. A weak heart can lead to congestive heart failure. There are many effective medications and therapies for the treatment of congestive heart failure. We recommend treatment according to our heart failure pathway outlined in Chapter 9.

**CONCLUSION**

Until recently, victims of OHCA seldom survived and most of those who did survive were left with severe, permanent disability. Only a small percentage of cardiac arrest survivors were able to recover normal brain function and return to live a normal life. Advances in the management of cardiac arrest, particularly the use of therapeutic hypothermia, have greatly improved the likelihood of survival without significant disability. We have described our protocol for the comprehensive management of OHCA. Implementation of protocols such as ours, and familiarity with the use of therapeutic hypothermia, provides victims of cardiac arrest with a much improved chance of a meaningful survival.