

# INTRODUCTION

**C**ardiac arrest is the cessation of normal circulation of the blood due to failure of the heart to contract effectively (*Jameson et al., 2005*).

Cardiopulmonary resuscitation (CPR) provides minimal circulatory support during cardiac arrest (*Singer and Webb, 2005*).

CPR is used in cardiac arrest in order to oxygenate the blood and maintain a cardiac output to keep vital organs alive. Blood circulation and oxygenation are absolute requirements in transporting oxygen to the tissues. The brain may sustain damage after blood flow has been stopped for about four minutes and irreversible damage after about seven minutes (*Brass and Lawrence, 2009*).

Basic Life support (BLS) is the foundation for saving lives following cardiac arrest. Fundamental aspects of adult BLS include immediate recognition of sudden cardiac arrest and activation of the emergency response system, early performance of high quality CPR, and rapid defibrillation when appropriate (*Field et al., 2010*).

Advanced Cardiac Life Support (ACLS) interventions aimed at preventing cardiac arrest include airway management, ventilation support, and treatment of bradyarrhythmias and

tachyarrhythmias. For the treatment of cardiac arrest, ACLS interventions build on the BLS foundation to further increase the likelihood of Return of Spontaneous Circulation (ROSC) with drug therapy, advanced airway management, and physiologic monitoring (*Neumar et al., 2010*).

Patients may be turned to the prone position, either in the operating theatre for better surgical access (e.g. neurosurgery, spinal surgery), or, more recently, to improve oxygenation in patients with acute respiratory distress syndrome (*Yien, 2006*).

CPR in the lateral position has been described in only a few reports in the past and is described in modifications to BLS guidelines for cardiac arrest during pregnancy (*Tetsuhiro et al., 2010*).

A combination of novel techniques and broad implementation strategies will almost certainly yield further improvement in our efforts to resuscitate patients who suffer cardiopulmonary arrest (*Jonas et al., 2006*).

*Chapter I***PATHOPHYSIOLOGY OF CPR****Anatomy and Physiology: Understanding the Importance of CPR**

**A**ll organs need oxygen to function. Three body systems work together to be sure that organs of the body have enough oxygen:

1. Respiratory system (brings oxygen in and takes waste out)
2. Cardiovascular system (moves blood and oxygen around)
3. Nervous system (tells organs what to do and when)

The respiratory, cardiovascular, and nervous systems work together to maintain life. The lungs put oxygen in the blood, and the heart delivers oxygen-rich blood to the heart itself and to the brain and other organs.

**The Respiratory System: Airways, Lungs, and Muscles**

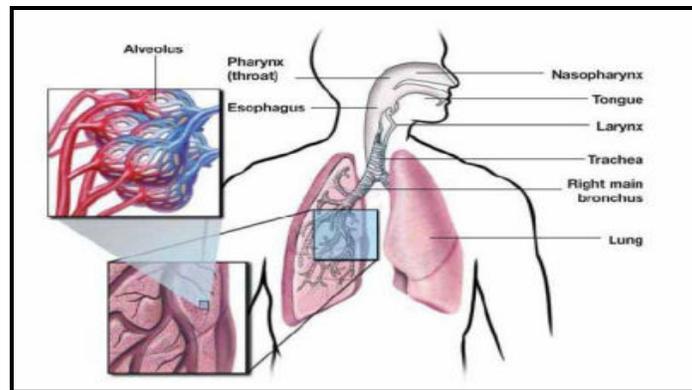
Anatomy of the Respiratory System:

The respiratory system (Figure 1-1) has 4 parts:

1. The airways that conduct air between the outside and the lungs

2. The air sacs (alveoli) in the lungs where gas exchange happens
3. The nerves that tell the muscles when to move and let the air move in and out.
4. A set of blood vessels that move the blood to the organs and removes waste from the blood (Table 1-1)

*(Erdmann, 2011)*



**Figure (1-1):** Anatomy of the respiratory system *(American Heart Association, 2006)*.

**Table (1-1):** Functions of pulmonary arteries, capillaries, and veins

<b>Part</b>	<b>Function</b>
Pulmonary arteries	Carry blood with relatively low oxygen content from the right side of the heart into the capillaries surrounding the alveoli.
Pulmonary Capillaries	Create a web surrounding the alveoli. At the interface between the capillaries and the alveoli, oxygen moves from the alveoli into the capillaries and carbon dioxide moves from the capillaries into the alveoli.
Pulmonary veins	Carry blood with high oxygen content from the lungs back to the left side of the heart.

### **Physiology of the Respiratory System**

The respiratory system has two primary functions:

1. Bringing oxygen from the air to the alveoli where it can move into blood
2. Eliminating carbon dioxide that moves from the blood into the alveoli

All body cells need a continuous supply of oxygen to function. Metabolism (the work of the cells) produces carbon dioxide, which the body must eliminate (*Easterbrook, 2005*).

## **Mechanics of Breathing**

Inspiration (breathing in) is an active process, while exhalation (breathing out) is generally a passive process. The diaphragm is the chief muscle of inspiration.

The following list shows the process of breathing:

- Two sets of muscles contract at the same time - the diaphragm and the muscles between the ribs (the intercostal muscles). The diaphragm contracts and moves down toward the abdomen, increasing the volume inside the chest. The intercostal muscles contract and lift the rib cage, further increasing the volume inside the chest.
- When the volume in the chest increases, the pressure in the chest and lungs falls.
- The difference in pressure between the outside air and the lungs draws air into the lungs.
- As the muscles relax, the ribs move down and the diaphragm rises, reducing the volume of the chest cavity.

The elastic lung passively becomes smaller, and the air inside the lung moves out (exhalation) (*Easterbrook, 2005*).

## **The Cardiovascular System**

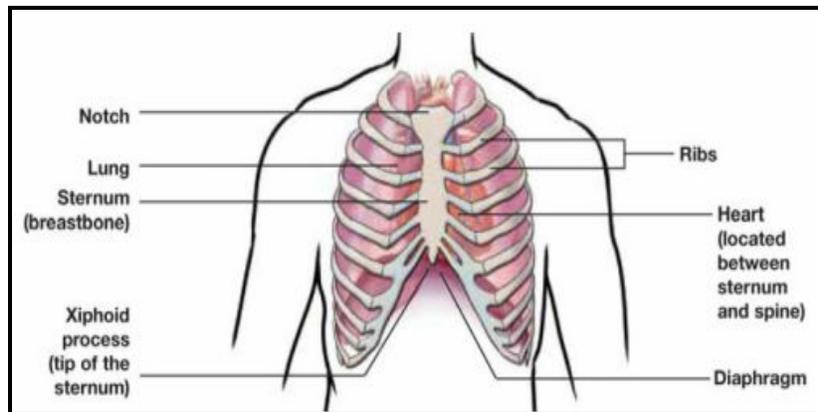
Anatomy of the Cardiovascular System:

The parts of the cardiovascular system are the

1. Heart
2. Arteries
3. Capillaries
4. Veins

### **Heart:**

The heart of an adult is not much larger than a fist. It lies in the center of the chest, behind the breastbone, in front of the backbone, and above the diaphragm. Except for the area against the backbone and a small strip down the center of the front of the heart, the heart is surrounded by lung (Figure 1- 2) (*American heart association, 2006*).



**Figure (1-2):** The heart in relation to other components of the chest (*American heart association, 2006*)

## Physiology of the Heart

The function of the heart is to pump blood to the lungs and to the body (including the heart and brain). Arteries and veins carry the blood between the organs of the body and the heart. In the tissues, oxygen and carbon dioxide are exchanged between the blood and the cells. This exchange takes place at the organ's capillaries (*Easterbrook, 2005*).

All body cells need a continuous supply of oxygen to carry out normal functions. Work of the cells (metabolism) produces carbon dioxide as a waste product. The heart is actually a double pump. (Table 1-2)

**Table (1-2):** Functions of the heart (*Easterbrook, 2005*)

Side of the heart	Function
Right	<ul style="list-style-type: none"><li>• Upper chamber receives blood that has returned from the body after delivering oxygen to body tissues</li><li>• Lower chamber pumps this dark, bluish-red blood to the lungs, where the blood:<ul style="list-style-type: none"><li>– Rids itself of carbon dioxide</li><li>– Picks up a supply of oxygen, which gives the oxygen-rich blood a bright red color</li></ul></li></ul>
Left	<ul style="list-style-type: none"><li>• Upper chamber receives the oxygen-rich blood from the lungs</li><li>• Lower chamber pumps blood into the aorta, which leads to smaller arteries that distribute it to all parts of the body</li></ul>

Each contraction of the heart, or heartbeat, is begun by an electrical impulse. The heart has its own electrical stimulation center called a pacemaker. A special system sends this electrical impulse to the heart muscle and makes it contract. The contraction is followed by a period of relaxation. During relaxation, the chambers of the heart fill with blood. This blood is ready to be pumped out by the ventricles with the next contraction (*Easterbrook, 2005*).

### **The Cerebrovascular System**

**Anatomy of the Brain** The central nervous system is composed of the brain and spinal cord (Table 1-3)

**Table (1-3):** Parts of Cerebrovascular system

<b>Part</b>	<b>Description</b>
Cerebrum	<ul style="list-style-type: none"> <li>• The largest portion of the brain</li> <li>• Has nerve centers that control most sensory and motor activities of the body</li> </ul>
Hemispheres	<ul style="list-style-type: none"> <li>• The cerebrum is divided into right and left halves, or hemispheres.</li> <li>• Each hemisphere contains a complete set of sensory and motor centers.</li> <li>• Generally, the right hemisphere controls the left side of the body, and the left hemisphere controls the right side of the body.</li> </ul>
Lobes	<ul style="list-style-type: none"> <li>• The cerebral hemispheres are further subdivided into lobes, or sections with specific, distinct functions.</li> </ul> <p>Lack of blood supply to brain tissue in a specific area can therefore result in distinct and limited loss of the specific function controlled by that area of the brain.</p>
Brain stem	<ul style="list-style-type: none"> <li>• The lower part of the brain.</li> <li>• Made up of bundles and tracts of nerves that travel down to the spinal cord from the cerebrum.</li> <li>• Includes distinct centers that monitor and control respiratory and circulatory function.</li> </ul>

*(FitzGerald and Folan-Curran, 2002)*

**Interaction of Respiratory, Cardiac and Brain Functions:**

The heart, lungs, and brain function interdependently. The lungs oxygenate the blood, and the heart delivers oxygenated blood to the brain. Cardiac arrest keeps oxygen from the brain and other vital organs. Sudden blocks of blood flow or hemorrhage (bleeding) within the brain - the condition we call stroke - will keep oxygen from a portion of the brain. In either case, this lack of oxygen will lead to a loss of brain function. Brain function also affects cardiac and respiratory function, with special centers in the brain control (*American Heart Association, 2006*).

***Pathophysiology of CPR*****The Mechanism of Blood Flow During CPR:**

The mechanism of blood flow produced during CPR has been a controversial and debated topic for several decades. Just how blood flow is produced became an important issue in trying to determine the optimal external chest compression rate. In 1977, Taylor and colleagues suggested that within the range of 40 to 80 compressions per minute, the duration of chest compression was more important than the rate of compression (*Taylor et al., 1977*).

This ratio of the duration of compression to decompression is the “duty cycle.” A duty cycle of 50% (50% of the time the chest is compressed and 50% decompressed,

generally by passive recoil) with 60 compressions per minute was initially thought optimal. In opposition to this concept, investigators at Duke University found that a higher chest compression rate produced better blood flow during closed chest CPR, up to a maximum rate of 140 compressions per minute (*Maier et al., 1984*).

Above a compression rate of 140/min, the relaxation or diastolic period for coronary filling is compromised to the point where total myocardial blood flow diminishes. In recognition of these findings, the National Conference on CPR in 1985 recommended increasing the chest compressions to 80 to 100/min (*Standards and guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC), 1986*).

#### **Current Concepts on Blood Flow during CPR:**

It appears that the mechanism of blood flow during CPR can vary accorded to the CPR technique utilized and the duration of cardiac arrest. It appears that the mechanism of blood flow during cardiopulmonary resuscitation can vary accorded to the CPR technique utilized. Cardiac/vascular compression is greatest with open-chest cardiac massage or high-impulse CPR, particularly in smaller subjects, while it is lowest with cough CPR or vest CPR. The mechanism of blood-flow generation also seems to vary with the duration of CPR efforts. Cardiac compression predominates as the mechanism

early in CPR, with the thoracic pump mechanism more predominant as time progresses (*Higano et al., 1990*).

In summary, the mechanism of blood-flow generation during CPR depends on body habitus, the duration of CPR, and the CPR technique utilized. Both mechanisms appear feasible and are probably present in each subject resuscitated (*Mattu et al., 2009*).

### **Pathophysiology of cardiac arrest:**

Cardiac arrest causes the complete cessation of forward blood flow, with resultant global ischemia affecting the entire organism. Various tissues have different tolerances to such global ischemia, but all will eventually succumb if blood flow is not restored in a timely fashion. The most prominent injuries occur in the central nervous system, which initially responds to ischemia with loss of consciousness after only 7 to 10 seconds of a circulatory arrest. Likewise, once the myocardial cells become globally ischemic, cellular function, including contraction, stops; if blood flow is not restored, myocytes begin to auto-infarct. The duration of no blood flow is crucial in these responses; hence the importance of CPR for restoring at least some modicum of flow during cardiac arrest. CPR restores only a portion of normal blood flow previously generated by a contracting heart. Nonetheless, such support is crucial for the survival of both the central nervous system and the myocardium (*Mattu et al., 2009*).

In Ventricular Tachycardia (VT) / Ventricular Fibrillation (VF), acute myocardial ischemia results in changes in the concentration of many components of the intracellular and extracellular milieu (e.g., pH, electrolytes, and ATP). In turn, these changes form the basis for pathogenic impulse formation and propagation of arrhythmia. In patients with areas of myocardial scarring, the mechanism for arrhythmia is likely to be a re-entrant circuit generated by surviving myofibrils within areas of fibrosis. Studies of non-ischaemic dilated cardiomyopathy have shown that the mechanism of arrhythmia is not re-entry, but more likely the initiation of VT/VF from early or late after-depolarisations in the setting of a prolonged action potential duration, which in turn is due to the altered function of various ion channels (*Kibos et al., 2014*).

*Chapter II***THE CHAIN OF SURVIVAL**

The actions linking the victim of sudden cardiac arrest with survival are called the **Chain of Survival** (*figure2-1*) and they include early recognition of the emergency and activation of the emergency services, early CPR, early defibrillation and early advanced life support (*Nolan et al., 2010*).

Sudden cardiac arrest (SCA) has many etiologies (i.e., cardiac or non-cardiac causes), circumstances (e.g., witnessed or unwitnessed), and settings (e.g., out-of-hospital or in-hospital). This heterogeneity suggests that a single approach to resuscitation is not practical, but a core set of actions provides a universal strategy for achieving successful resuscitation. These actions are termed the links in the “**Chain of Survival**” (*Berg et al., 2010*).

For adults they include:

- Immediate **recognition** of cardiac arrest and **activation** of the emergency response system.
- Early **CPR** that emphasizes chest compressions.
- Rapid **defibrillation** if indicated.
- Effective **advanced life support**.

- Integrated post– cardiac arrest care (*Berg et al., 2010*).



**Figure (2-1):** Chain of Survival. The links in this Chain are: immediate recognition and activation, early CPR, rapid defibrillation, effective advanced life support and integrated post-cardiac arrest care (2010 AHA Guidelines for CPR and ECC).

Since 1992, the chain of survival has been widely promoted and has become the underlying concept for the treatment of out-of-hospital cardiac arrest in many emergency medical services (EMS) systems. The importance of recognizing critical illness and/or angina and preventing cardiac arrest (in- or out-of-hospital), and post resuscitation care is now well accepted, and has been highlighted by the inclusion of these elements in a four-ring Chain of Survival (*Jacobs et al., 2001*).

In most emergency systems, however, survival is lower, indicating that there is an opportunity for improvement by carefully examining the links and strengthening those that are weak (*Nichol et al., 2008*).

The individual links are interdependent, and the success of each link is dependent on the effectiveness of those that precede it. Rescuers have a wide variety of training, experience,