HYPOXIA

DEFINITION

Hypoxia is defined as reduced availability of oxygen to the tissues. The term anoxia refers to absence of oxygen. In olden days, the term anoxia was in use. Since there is no possibility for total absence of oxygen in living conditions, use of this term is abandoned.

CLASSIFICATION AND CAUSES OF HYPOXIA

Four important factors which leads to hypoxia are:

1. Oxygen tension in arterial blood
2. Oxygen carrying capacity of blood
3. Velocity of blood flow
4. Utilization of oxygen by the cells.

On the basis of above factors, hypoxia is classified into four types:

1. Hypoxic hypoxia
2. Anemic hypoxia
3. Stagnant hypoxia
4. Histotoxic hypoxia.

Each type of hypoxia may be acute or chronic. Simultaneously, two or more types of hypoxia may be present.

1. *Hypoxic Hypoxia*

Hypoxic hypoxia means decreased oxygen content in blood. It is also called arterial hypoxia.

Causes for hypoxic hypoxia

Hypoxic hypoxia is caused by four factors.

i. Low oxygen tension in inspired (atmospheric) air, which does not provide enough oxygen
ii. Respiratory disorders associated with decreased pulmonary ventilation, which does not allow intake of enough oxygen
iii. Respiratory disorders associated with inadequate oxygenation in lungs, which does not allow diffusion of enough oxygen
iv. Cardiac disorders, in which enough blood is not pumped to transport oxygen.

i. *Low oxygen tension in inspired air*

Oxygen tension in inspired air is reduced in the following conditions:

a. High altitude
b. While breathing air in closed space
c. While breathing gas mixture containing low partial pressure of oxygen (PO_2).

Because of these conditions, required quantity of oxygen cannot enter the lungs.

ii. *Respiratory disorders associated with decreased pulmonary ventilation*

Pulmonary ventilation decreases in the following conditions:

a. Obstruction of respiratory passage as in asthma
b. Nervous and mechanical hindrance to respiratory movements as in poliomyelitis
c. Depression of respiratory centers as in brain tumors
d. Pneumothorax.

In these conditions, even though enough oxygen is available in the atmosphere, it cannot reach the lungs.

iii. *Respiratory disorders associated with inadequate oxygenation of blood in lungs*

Inadequate oxygenation of blood in lungs occurs in the following conditions:

a. Impaired alveolar diffusion as in emphysema
b. Presence of non-functioning alveoli as in fibrosis
c. Filling of alveoli with fluid as in pulmonary edema, pneumonia, pulmonary hemorrhage
d. Collapse of lungs as in bronchiolar obstruction
e. Lack of surfactant
f. Abnormal pleural cavity such as pneumothorax, hydrothorax, hemothorax and pyothorax
g. Increased venous admixture as in the case of bronchiectasis.

In these conditions, in spite of oxygen availability and entrance of oxygen into the alveoli, it cannot diffuse into the blood.

iv. *Cardiac disorders*

In congestive heart failure, oxygen availability and diffusion are normal, but the blood cannot be pumped from heart properly.

Characteristic features of hypoxic hypoxia

Hypoxic hypoxia is characterized by reduced oxygen tension in arterial blood. All other features remain normal (Table 127.1).

2. *Anemic Hypoxia*

Anemic hypoxia is the condition characterized by the inability of blood to carry enough amount of oxygen. Oxygen availability is normal. But the blood is not able to take up sufficient amount of oxygen due to anemic condition.

Causes for anemic hypoxia

Any condition that causes anemia can cause anemic hypoxia. It is caused by the following conditions:

i. Decreased number of RBCs
ii. Decreased hemoglobin content in the blood
iii. Formation of altered hemoglobin
iv. Combination of hemoglobin with gases other than oxygen and carbon dioxide.

i. *Decreased number of RBCs*

RBC decreases in conditions like bone marrow diseases, hemorrhage, etc.

ii. *Decreased hemoglobin content in the blood*

Conditions which decrease the RBC count or change the structure, shape and size of RBC (microcytes, macrocytes, spherocytes, sickle cells, poikilocytes, etc.) can decrease the hemoglobin content in blood.

iii. *Formation of altered hemoglobin*

Poisoning with chlorates, nitrates, ferricyanides, etc. causes oxidation of iron into ferric form and the hemoglobin is known as methemoglobin. Methemoglobin cannot combine with oxygen. Thus, the quantity of hemoglobin available for oxygen transport is decreased (Chapter 11).

iv. *Combination of hemoglobin with gases other than oxygen and carbon dioxide*

When hemoglobin combines with carbon monoxide, hydrogen sulfide or nitrous oxide, it looses the capacity to transport oxygen (Chapter 11).

Characteristic features of anemic hypoxia

Anemic hypoxia is characterized by decreased oxygen carrying capacity of blood. All other features remain normal (Table 127.1).

3. *Stagnant Hypoxia*

Stagnant hypoxia is the hypoxia caused by decreased velocity of blood flow. It is otherwise called hypokinetic hypoxia.

Causes for stagnant hypoxia

Stagnant hypoxia occurs mainly due to reduction in velocity of blood flow. Velocity of blood flow decreases in the following conditions:

i. Congestive cardiac failure
ii. Hemorrhage
iii. Surgical shock
iv. Vasospasm
v. Thrombosis
vi. Embolism.

Characteristic features of stagnant hypoxia

Stagnant hypoxia is characterized by decreased velocity of blood flow. All other features remain normal (Table 127.1).

4. *Histotoxic Hypoxia*

Histotoxic hypoxia is the type of hypoxia produced by the inability of tissues to utilize oxygen.

Causes for histotoxic hypoxia

Histotoxic hypoxia occurs due to cyanide or sulfide poisoning. These poisonous substances destroy the

TABLE 127.1: Characteristic features of different types of hypoxia

Features	Hypoxic hypoxia	Anemic hypoxia	Stagnant hypoxia	Histotoxic hypoxia
1. PO_2 in arterial blood	Reduced	Normal	Normal	Normal
2. Oxygen carrying capacity of blood	Normal	Reduced	Normal	Normal
3. Velocity of blood flow	Normal	Normal	Reduced	Normal
4. Utilization of oxygen by tissues	Normal	Normal	Normal	Reduced
5. Efficacy of oxygen therapy	100%	75%	< 50%	Not useful

cellular oxidative enzymes and there is a complete paralysis of cytochrome oxidase system. So, even if oxygen is supplied, the tissues are not in a position to utilize it.

Characteristic features of histotoxic hypoxia

Histotoxic hypoxia is characterized by inability of tissues to utilize oxygen even if it is delivered. All other features remain normal (Table 127.1).

■ EFFECTS OF HYPOXIA

Acute and severe hypoxia leads to unconsciousness. If not treated immediately, brain death occurs. Chronic hypoxia produces various symptoms in the body.

Effects of hypoxia are of two types:

1. Immediate effects
2. Delayed effects.

Immediate Effects

i. *Effects on blood*

Hypoxia induces secretion of erythropoietin from kidney. Erythropoietin increases production of RBC. This in turn, increases the oxygen carrying capacity of blood.

ii. *Effects on cardiovascular system*

Initially, due to the reflex stimulation of cardiac and vasomotor centers, there is an increase in rate and force of contraction of heart, cardiac output and blood pressure. Later, there is reduction in the rate and force of contraction of heart. Cardiac output and blood pressure are also decreased.

iii. *Effects on respiration*

Initially, respiratory rate increases due to chemoreceptor reflex. Because of this, large amount of carbon dioxide is washed out leading to alkalemia. Later, the respiration tends to be shallow and periodic. Finally, the rate and force of breathing are reduced to a great extent due to the failure of respiratory centers.

iv. *Effects on digestive system*

Hypoxia is associated with loss of appetite, nausea and vomiting. Mouth becomes dry and there is a feeling of thirst.

v. *Effects on kidneys*

Hypoxia causes increased secretion of erythropoietin from the juxtaglomerular apparatus. And alkaline urine is excreted.

vi. *Effects on central nervous system*

In mild hypoxia, the symptoms are similar to those of alcoholic intoxication.

Individual is depressed, apathetic with general loss of self control. The person becomes talkative, quarrelsome, ill-tempered and rude. The person starts shouting, singing or crying.

There is disorientation and loss of discriminative ability and loss of power of judgment. Memory is impaired. Weakness, lack of coordination and fatigue of muscles are common in hypoxia.

If hypoxia is acute and severe, there is a sudden loss of consciousness. If not treated immediately, coma occurs, which leads to death.

Delayed Effects of Hypoxia

Delayed effects appear depending upon the length and severity of the exposure to hypoxia.

The person becomes highly irritable and develops the symptoms of mountain sickness, such as nausea, vomiting, depression, weakness and fatigue.

■ TREATMENT FOR HYPOXIA – OXYGEN THERAPY

Best treatment for hypoxia is oxygen therapy, i.e. treating the affected person with oxygen. Pure oxygen or oxygen combined with another gas is administered.

Oxygen therapy is carried out by two methods:

1. By placing the patient's head in a 'tent' containing oxygen
2. By allowing the patient to breathe oxygen either from a mask or an intranasal tube.

Depending upon the situation, oxygen therapy can be given either under normal atmospheric pressure or under high pressure (hyperbaric oxygen).

HYPERCAPNEA

DEFINITION

Hypercapnea is the increased carbon dioxide content of blood.

CONDITIONS WHEN HYPERCAPNEA OCCURS

Hypercapnea occurs in conditions, which leads to blockage of respiratory pathway, as in case of asphyxia. It also occurs while breathing the air containing excess carbon dioxide content.

EFFECTS OF HYPERCAPNEA

1. *Effects on Respiration*

During hypercapnea, the respiratory centers are stimulated excessively. It leads to dyspnea.

2. *Effects on Blood*

The pH of blood reduces and blood becomes acidic.

3. *Effects on Cardiovascular System*

Hypercapnea is associated with tachycardia and increased blood pressure. There is flushing of skin due to peripheral vasodilatation.

4. *Effects on Central Nervous System*

During hypercapnea, the nervous system is also affected, resulting in headache, depression and laziness. These symptoms are followed by muscular rigidity, fine tremors and generalized convulsions. Finally, giddiness and loss of consciousness occur.

HYPOCAPNEA

DEFINITION

Hypocapnea is the decreased carbon dioxide content in blood.

CONDITIONS WHEN HYPOCAPNEA OCCURS

Hypocapnea occurs in conditions associated with hypoventilation. It also occurs after prolonged hyperventilation because of washing out of excess carbon dioxide.

■ EFFECTS OF HYPOCAPNEA

1. *Effects on Respiration*

Respiratory centers are depressed, leading to decreased rate and force of respiration.

2. *Effects on Blood*

The pH of blood increases, leading to respiratory alkalosis. Calcium concentration decreases. It causes tetany, which is characterized by neuromuscular hyperexcitability and carpopedal spasm.

3. *Effects on Central Nervous System*

Dizziness, mental confusion, muscular twitching and loss of consciousness are the common features of hypocapnea.

Artificial Respiration

CONDITIONS WHEN ARTIFICIAL RESPIRATION IS REQUIRED

Artificial respiration is required whenever there is an arrest of breathing, without cardiac failure. Arrest of breathing occurs in the following conditions:

1. Accidents
2. Drowning
3. Gas poisoning
4. Electric shock
5. Anesthesia.

Stoppage of oxygen supply for 5 minutes causes irreversible changes in tissues of brain, particularly tissues of cerebral cortex. So, artificial respiration (resuscitation) must be started quickly without any delay, before the development of cardiac failure.

Purpose of artificial respiration is to ventilate the alveoli and to stimulate the respiratory centers.

METHODS OF ARTIFICIAL RESPIRATION

Methods of artificial respiration are of two types:

1. Manual methods
2. Mechanical methods.

MANUAL METHODS

Manual methods of resuscitation can be applied quickly without waiting for the availability of any mechanical aids.

Affected person must be provided with clear air. Clothes around neck and chest regions must be loosened. Mouth, face and throat should be cleared of mucus, saliva, foreign particles, etc. Tongue must be drawn forward and it must be prevented from falling posteriorly, which may cause airway obstruction.

Manual methods are of two types:

i. Mouth-to-mouth method
ii. Holger Nielsen method.

Mouth-to-mouth Method

The subject is kept in supine position and the resuscitator (person who give resuscitation) kneels at the side of the subject. By keeping the thumb on subject's mouth, the lower jaw is pulled downwards. Nostrils of the subject are closed with thumb and index finger of the other hand.

Resuscitator then takes a deep breath and exhales into the subject's mouth forcefully. Volume of exhaled air must be twice the normal tidal volume. This expands the subject's lungs. Then, the resuscitator removes his mouth from that of the subject. Now, a passive expiration occurs in the subject due to elastic recoil of the lungs. This procedure is repeated at a rate of 12 to 14 times a minute, till normal respiration is restored.

Mouth-to-mouth method is the most effective manual method because, carbon dioxide in expired air of the resuscitator can directly stimulate the respiratory centers and facilitate the onset of respiration. Only disadvantage is that the close contact between the mouths of resuscitator and subject may not be acceptable for various reasons.

Holger Nielsen Method or Back Pressure Arm Lift Method

Subject is placed in prone position with head turned to one side. Hands are placed under the cheeks with flexion at elbow joint and abduction of arms at the shoulders. Resuscitator kneels beside the head of the subject. By placing the palm of the hands over the back of the subject, the resuscitator bends forward with straight arms (without flexion at elbow) and applies pressure on the back of the subject.

Weight of the resuscitator and pressure on back of the subject compresses his chest and expels air from the lungs. Later, the resuscitator leans back. At the same time, he draws the subject's arm forward by holding it just above elbow.

This procedure causes expansion of thoracic cage and flow of air into the lungs. The movements are repeated at the rate of 12 per minute, till the normal respiration is restored.

MECHANICAL METHODS

Mechanical methods of artificial respiration become necessary when the subject needs artificial respiration for long periods. It is essential during the respiratory failure due to paralysis of respiratory muscles or any other cause.

Mechanical methods are of two types:

i. Drinker method
ii. Ventilation method.

Drinker Method

The machine used in this method is called iron lung chamber or tank respirator. The equipment has an airtight chamber, made of iron or steel. Subject is placed inside this chamber with the head outside the chamber.

By means of some pumps, the pressure inside the chamber is made positive and negative alternately. During the negative pressure in the chamber, the subject's thoracic cage expands and inspiration occurs and during positive pressure the expiration occurs.

By using tank respirator, the patient can survive for a longer time, even up to the period of one year till the natural respiratory functions are restored.

Ventilation Method

A rubber tube is introduced into the trachea of the patient through the mouth. By using a pump, air or oxygen is pumped into the lungs with pressure intermittently. When air is pumped, inflation of lungs and inspiration occur. When it is stopped, expiration occurs and the cycle is repeated. Apparatus used for ventilation is called ventilator and it is mostly used to treat acute respiratory failure.

Ventilator is of two types:

a. Volume ventilator
b. Pressure ventilator.

Volume ventilator

By volume ventilator, a constant volume of air is pumped into the lungs of patients intermittently with minimum pressure.

Pressure ventilator

By pressure ventilator, air is pumped into the lungs of subject with constant high pressure.