Chapter 20

HYPOXIA

(ANOXIA)

Hypoxia refers to an inadequate level of oxygen (O_2) within the cells. **Anoxia** implies there is no O_2 left at all in the cells, and is uncommon. Without O_2 most cells, especially those of the brain, die within a few minutes. This is the final outcome of many diving accidents and is often the ultimate cause of death.

Hypoxia is caused by an interruption in the chain of physiological processes (see Chapters 3 & 4) which bring O_2 from the outside air (or breathing gas) to the body's cells. There are **four links** in this chain where interruption can cause hypoxia, supplying a logical classification.

CLASSIFICATION OF HYPOXIA

HYPOXIC HYPOXIA

Inadequate Oxygen content in Arterial Blood

In diving, the most common form of hypoxia is **hypoxic hypoxia**. This usually follows an inadequate air supply and/or salt water aspiration or drowning. Either there is inadequate O_2 getting to the lungs because the diver has, for a variety of reasons, only water to breathe, or the lungs are unable to convey inhaled O_2 to the blood because of alveolar damage due to near drowning.

An inadequate air supply can also arise from an inadequate concentration of O_2 in the breathing gas (e.g. a gas mixture in which O_2 has been inadvertently omitted or an internally rusty scuba cylinder which extracts O_2). It may develop from equipment failure or obstruction somewhere in the respiratory tract between the nose or mouth and the alveoli, due to :

- upper airway obstruction due to unconsciousness

- tracheal obstruction from inhalation of vomit and
- alveolar damage from salt water inhalation (see Chapters 25 and 26).

Pulmonary barotrauma is another cause. A less common, but often catastrophic, cause is decompression sickness, when the gas bubbles are carried to the lungs in such quantities that the lungs cannot cope with them – resulting in "chokes".

STAGNANT HYPOXIA

O_2 Taken Up by the Blood Fails to Reach the Tissues

This is generally due to failure of the heart to pump the blood adequately to the tissues (e.g. from a heart attack or air embolism). Poor circulation to the extremities in cold conditions can cause localised hypoxia to these areas without generalised hypoxia.

ANAEMIC HYPOXIA

Inability of the Blood to Carry O_2 in the Presence of Adequate Circulation

This is generally due to inadequate amounts of circulating functional haemoglobin, usually from blood loss or carbon monoxide poisoning (see Chapter 23).

HISTOTOXIC HYPOXIA

Inability of the Cells to Use the O_2

This is caused by certain poisons including carbon monoxide (see Chapter 23).

HYPOXIA IN BREATHHOLD DIVING

Drowning Syndromes

See Chapters 25 and 26. The inhalation of water into the lungs is the commonest cause of hypoxia in all types of recreational diving.

Hyperventilation

As explained in Chapter 4, hyperventilation before a breath-hold dive reduces the urge to breathe during the dive and may cause the diver to lose consciousness from hypoxia while still underwater (see Case Histories 33.2, 33.3) and with little or no warning. Drowning frequently results from this.

Hypoxia of Ascent

The partial pressure of O_2 in the lungs falls as they expand during ascent from a breath-hold dive. In some circumstances, this can cause loss of consciousness from hypoxia during ascent. Details are explained fully in Chapter 4.

HYPOXIA IN COMPRESSED GAS DIVING

Scuba

Exhaustion of the air supply, equipment malfunction, regulator resistance or loss of the demand valve will leave the diver with nothing but water to breathe – inevitably resulting in hypoxia due to salt water aspiration or drowning. Panic and poor dive techniques are often precursors to these problems.

Diving induced asthma, pneumothorax (from pulmonary barotrauma) and decompression sickness (chokes) can also interfere with breathing sufficient to cause hypoxia.

Rebreathing Equipment

This type of equipment shares the same causes of hypoxia as scuba equipment, but has some additional hazards.

A hypoxic gas mixture can be breathed if the **wrong gas** or **wrong mixture** is used (i.e. a gas mixture containing insufficient O_2). A specific example of this is when a gas mixture intended for use at great depth (e.g. one containing 5% O_2) is breathed near the surface. With rebreathing equipment using a constant flow of gas, the **flow of O_2** must be sufficient for the energy needs of the diver, and this will increase with **exertion**. Thus, O_2 concentrations too low, inadequate flow rates or excessive O_2 consumption may all lead to hypoxia in rebreathers.

Dilutional hypoxia is a particular problem with rebreathing equipment. When the diver first begins to breathe from the diving set, a significant amount of nitrogen may be displaced from the lungs and body into the counterlung (breathing bag) of the equipment. If this is not vented after a few minutes breathing, the diver is likely to rebreathe almost pure nitrogen from the rebreathing bag. Oxygen is consumed by the diver and the carbon dioxide produced is absorbed by chemicals used in the equipment. Because the counterlung will still contain gas

(mostly nitrogen) the diver will be unaware of the danger. The O_2 % may be adequate at depth, but not near the surface.

CLINICAL FEATURES

In most cases of hypoxia, the diver is unaware that there is anything wrong and therefore can lose consciousness without warning.

Mild hypoxia starves the brain of O_2, causing confusion, impaired judgment and clouding of consciousness. The diver is frequently unaware that there is a problem and may even become over-confident. Sometimes he may notice a loss of colour vision, but this is infrequent. An observer should notice a deterioration of performance.

More **profound hypoxia** causes unconsciousness and in some cases, muscular jerking and spasms (especially of the jaw muscles) or epileptic type fits. **Severe hypoxia** results in rapid death.

Hypoxia makes the blood blue in colour. Hypoxic blood in the body capillaries gives the skin a blue appearance, and is termed **cyanosis**. It is not easily detected under the blue water, but is often obvious when the diver is surfaced

There is a form of localised cyanosis (stagnant hypoxia) associated with **cold** which does not denote generalised hypoxia. This is seen in the fingers and ears, due to (peripheral) blood vessel constriction causing inadequate circulation in these areas, in response to cold. It can be distinguished from the cyanosis of generalised hypoxia (hypoxic hypoxia) by looking at the colour of the tongue. The tongue is blue only in the generalised hypoxia.

TREATMENT

If hypoxia is due to insufficient O_2 in the cells, treatment should aim to reverse this. The basic resuscitation principles should be applied first (see Chapter 42).

A. Clear the airway.
B. Establish or maintain breathing.
C. Establish or maintain circulation.

Give the patient the highest possible O_2 concentration to breathe and use positive pressure if needed (see Chapter 40).

All diving operations should be undertaken with emergency O_2 equipment available, sufficient to last until the diver can access more formal medical facilities. A rule of thumb is to allow for 15 litres of O_2 per minute. There should always be at least one person, who is not diving, cognisant of and trained in the application of the O_2 equipment. This is usually the boatman or dive master.

PREVENTION

Most diving deaths are ultimately caused by the hypoxia associated with drowning, regardless of the initial problem. In many cases this can be avoided by the **buddy system**, which permits the diver to be rescued and employ positive **buoyancy** for the victim**.** A good buoyancy compensator should keep even an unconscious diver's face clear of the water.

Avoid prolonged or deep **breath-hold dives**. **Never hyperventilate** before a breath-hold dive and avoid exertion as much as possible.

With **scuba,** maintain equipment adequately and check it before a dive. **Monitor the air supply** continuously, using a contents gauge.

With **re-breathing equipment**, check the O_2 concentrations before diving, also the gas flows and pressures. Avoid excessive exertion and flush through with appropriate gas before ascending.