Chapter 4

BREATH-HOLD DIVING

Free, breath-hold or snorkel diving is a prerequisite for successful scuba diving. The diver can thus become comfortable in the aquatic environment and gradually learn the swimming and snorkeling skills that may later be used in reaching dive sites and remaining safe even after the scuba set has been exhausted. One extension of snorkeling is free diving, used to spear fish, prolong underwater explorations, retrieve equipment, check anchors and many other activities .

It is not difficult for a diver to perform a breath-hold dive for a duration of one minute or more. This is possible because there is a reservoir of oxygen (O_2) stored in the lungs (about 1 litre O_2 when the lungs are full), in blood haemoglobin, and in myoglobin in the muscles.

With these reserves the diver is able to hold his breath for some time without the blood level of O_2 becoming dangerously low. Below a threshold blood O_2 partial pressure (about 30mm Hg – less than half the normal value), the brain ceases to function properly, causing loss of consciousness. At about this stage, the heart also becomes seriously starved of O_2 causing cardiac damage or disturbances of rhythm.

During a breath-hold dive, O_2 is consumed and carbon dioxide (CO_2) produced, decreasing the blood level of O_2 and elevating that of CO_2. Both effects may stimulate respiration but the CO_2 is the more dominant. Usually the diver develops an overpowering desire to breath (he reaches the **break point**) before the arterial O_2 level falls to a dangerous value. The urge to breath eventually becomes irresistible and the diver may even take a breath under water, if he is unable to reach the surface in time.

Breath-holding can be extended considerably, with experience and will-power but the break point is eventually reached. This is nature's safety mechanism to prevent people from losing consciousness from excessively prolonged breath-holding (see Case Histories 33.2 and 33.3).

ACCIDENTS and DEATHS

Breath-hold divers suffer from the same problems as scuba divers, except for those related to compressed gas inhalation. The common problems include environmental hazards, some equipment limitations and medical diseases such as the barotraumas, marine animal injuries,

infections, hypothermia, panic and fatigue, cardiac disorders and the drowning syndromes. These are discussed in the chapters dealing with scuba diving medicine.

In an Australian series of snorkeling deaths, the causes were dominated by drowning (45%), Cardiac disease (30%) and hypoxic blackout (20%). The first two were mainly in aquatically unfit, older tourists, and the last in younger, aquatically fit and experienced free divers. The inevitable predominance of time on the surface makes the breath-hold diver more susceptible to sunburn, boat injury and tidal currents.

The other problems more associated with breath-hold divers are discussed here.

Lung Squeeze (Pulmonary Barotrauma of Descent)

During a breath-hold dive the chest and lungs are compressed by the increasing pressure of water. As the air in the lungs is compressed, the volume is replaced to a limited degree by expansion and engorgement of the lung's blood vessels. Lung injury from this mechanism is known as lung squeeze, or pulmonary barotrauma of descent (see Boyle's Law, Chapter 2).

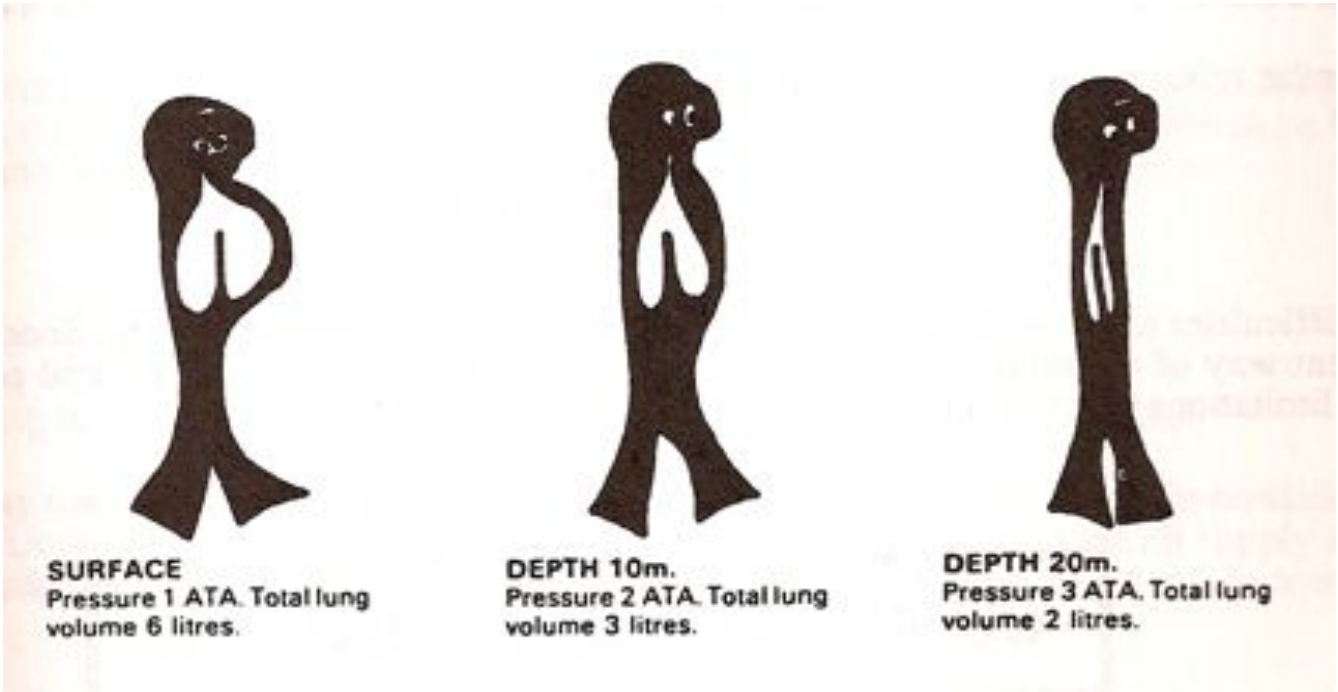

Fig. 4.1

Theoretically, the maximum safe depth for most divers should be about 30 metres (4ATA), but it probably varies between individuals, as much deeper breath-hold dives have now been performed - in excess of 200 metres.

Immersion

A neutrally buoyant diver is exempt from the main effects of gravity and this produces physiological changes in the body. The return of blood flow to the heart and lungs is increased. The body interprets this as an excess blood volume and compensates by **increasing urine production (**which may then lead to **dehydration)**.

Cold water exposure produces many reflexes, including a desire to urinate. Temperature regulation is more difficult. The pressure variations may influence lung function with head out or vertical positions. Spatial orientation processes are disrupted. Trauma, in the form of physical injury from water movement, marine infections, dangerous marine animals, barotraumas, drowning etc. are dealt with in separate chapters.

Dive Reflex

Aquatic mammals display a reflex known as the "**dive reflex**". This is associated with profound slowing of the heart and redirection of the blood flow away from the muscles and non-essential organs to give a better blood supply to the heart and brain. It allows for longer submersions. This reflex is present to a less degree in humans and can be produced by immersing the face or head in cold water. The heart slowing component of the reflex has been used by physicians to treat certain cardiac disorders associated with a rapid heart rate. It can also result in heart arrhythmias.

Other potentially harmful reflexes can be induced by cold, Valsalvas, breath-holding *etc*.

Hypoxic Blackout

This loss of consciousness, due to an inadequate supply of $\mathbf{O_2}$ to the brain, usually develops without any warning. Underwater this leads to aspiration of water and drowning. It is a frequent cause of deaths amongst breath-hold divers. Sometimes the diver arrives on the surface still alive but in a state almost unconscious, and with some brain damage. This is called LMC (Loss of Motor Control) and causes unsteadiness and clumsiness. It also may occur after the diver has been rescued while unconscious or semi-conscious. At other times it may result in dementia, severe muscle impairment, visual damage or epileptic convulsions. There are two main types of hypoxic blackout, although they can occur together.

a. Hypoxic Blackout due to Hyperventilation and Breath-holding

There are some people who find the flaunting of safety mechanisms an overwhelming challenge. They may be trying to swim or stay underwater for as long as possible (such as swimming the length of a swimming pool, or to impress their peers or girl friend). The break point can be delayed by **hyperventilating** (taking a succession of rapid deep breaths) before a dive. This reduces lung and arterial CO_2 so that it takes longer for the blood level to reach the break point during a dive. During this delay, the blood O_2 level may fall below that necessary to maintain consciousness and the diver may become unconscious without any warning. This is one cause of **Hypoxic Blackout**. This can occur at any depth, such as in a one metre deep pool. Using this method some divers have been able to prolong their breath hold dives for extended periods — until the body is found!

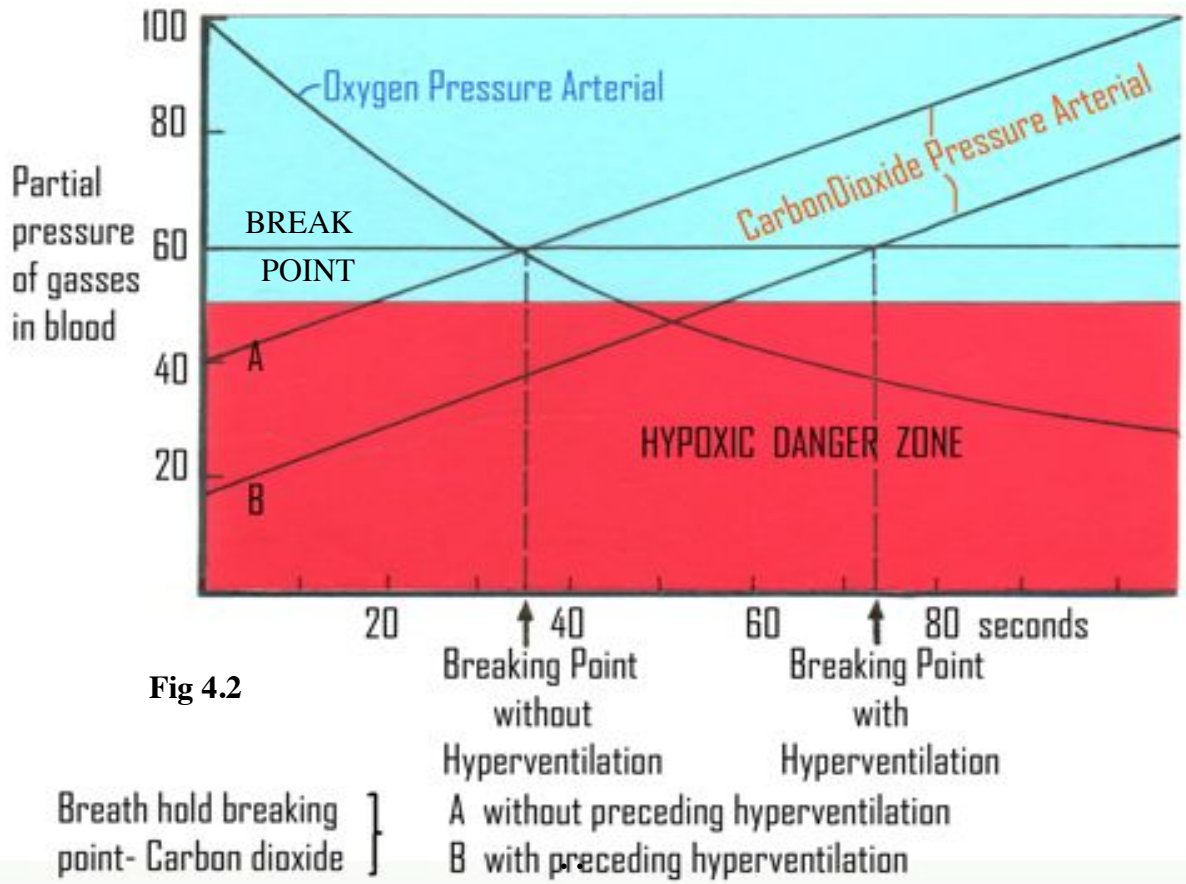

Fig 4.2

This diagram shows the relationship between the fall of oxygen and carbon dioxide levels in the blood with breath-holding. Normally, with breath-holding, (A) the breaking point is reached before the hypoxic zone is reached. After hyperventilation and breath-holding, (B) the breaking point is in the hypoxic zone.

b. Hypoxic Blackout due to Hypoxia of Ascent

Most divers will have noticed during a breath-hold dive that the desire to breathe often decreases with depth. This is probably due to the partial pressure of O_2 in the lungs increasing as they are compressed. There is a corresponding rise in the partial pressure of O_2 in the blood which will reduce the hypoxic stimulus to breathing. At depth the diver continues to exercise and use up his O_2 reserves. As the diver ascends however, the lungs will expand and the partial pressure of O_2 in them will correspondingly decrease. This produces an abrupt reduction in the O_2 partial pressure in the blood. It may fall below the threshold and cause unconsciousness during or immediately after ascent. This phenomenon is termed **hypoxia of ascent**. It may even occur after a diver has taken the first breath after surfacing, because of the delay between taking this breath and the replenished oxygen reaching the brain.

Some divers, especially those who are spear fishing, taking photographs or deep breath-hold diving for other reasons, will not only hyperventilate first, but then dive deep until they feel the necessity to breath (the break point). These are exposed to the dangers both of hyperventilation and breath-holding, and also to hypoxia of ascent. Death in such breath-hold divers is common, as unconsciousness occurs without warning.

Hypoxic Blackout - Prevention

1. Do not hyperventilate before breath-holding
2. Do not dive deep
3. Avoid excessive exercise
4. Avoid competitive behaviour resulting in the above activities
5. Ensure buoyancy near the surface
6. Dive with a buddy or have a safety observer/rescuer
7. Educate breath-hold divers of this hazard

Snorkel Diving

All the difficulties associated with breath-hold diving occur with snorkel diving – which is just breath-hold diving with a snorkel. Snorkel breathing is a convenient way of obtaining air whilst on the surface and with the head immersed, however it has several physiological and physical limitations due to the snorkel's structure (see Chapter 5).

MEDICAL CHECKLIST FOR SNORKELLERS

Have you ever had any of the following medical conditions :

1. Any cardiovascular disease? (Heart, blood pressure, blood, etc).	YES	NO
2. Any lung disease? (Asthma, wheezing, pneumothorax, TB, etc.)	YES	NO
3. Any fits, epilepsy, convulsions or blackouts?	YES	NO
4. Any serious disease? (Such as diabetes)	YES	NO
5. Serious ear, sinus or eye disease?	YES	NO
6. Any neurological or psychiatric disease?	YES	NO
7. Any family history of heart disease?	YES	NO

Over the last month have you had any of the following :

8. Operations, illnesses, treatment?	YES	NO
9. Drugs or medications?	YES	NO
10. If female, are you pregnant?	YES	NO
11. Can you swim 500 metres without aids?	NO	YES
12. Can you swim 200 metres in 5 minutes or less?	NO	YES

NAME :

DoB :

ADDRESS :
(If under 16 years, guardian to sign.)

Note : If the candidate indicates an answer in the left hand column, then further investigation or action is required before snorkelling is considered as safe.