

## Chapter 35

# SUDDEN DEATH SYNDROME (Cardiac Death)

### **PATHOLOGY**

Sudden death in divers, especially middle aged divers, is not a rare event. The usual cause is cardiac — either a fatal disturbance of cardiac rhythm (arrhythmia), heart muscle death from a blockage of a diseased coronary artery (coronary occlusion causing ischaemia, myocardial infarction or "heart attack"), or a disease of the heart muscle itself (myocarditis, cardiomyopathy).

Statistical studies on deaths in diving show a disturbingly high incidence of death attributed to heart disease, and rising. In the DAN series, 26% of deaths were cardiac and they contributed to 45% of the scuba deaths in those over 40 years. They tend to be in more experienced divers, associated with known cardiac history, arrhythmias or ischaemia, hypertension or the use of cardio-active drugs.

### **Cardiac Arrhythmias**

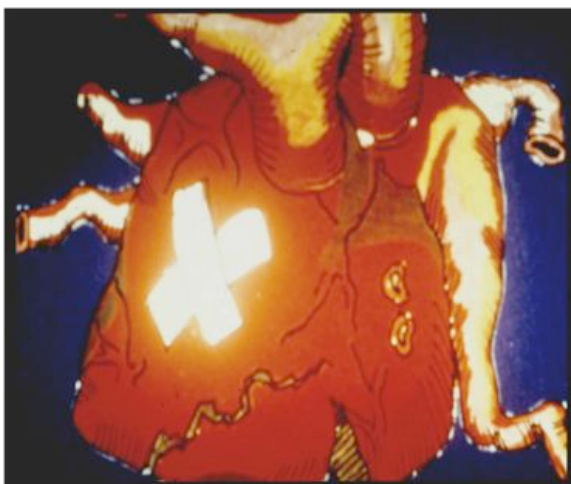
The heart normally beats in an orderly and regular way (see Chapter 3). The atria contract, first propelling blood into the ventricles which then in turn contract, ejecting blood into the major arteries.

If this rhythmic contraction is disturbed (an arrhythmia or "irregular heart beat"), the efficiency of cardiac function is impaired and the heart has to work harder, requiring more oxygen and blood flow of its own. Impaired efficiency may also cause lowered blood pressure, which can reduce blood flow to the brain, causing unconsciousness. The

arrhythmia which causes sudden death is called **ventricular fibrillation**, and this usually results in unconsciousness within a few seconds and death within a few minutes.

Severe arrhythmias tend to occur in divers who already have less severe arrhythmias, those with cardiac ischaemia, cardiomyopathies or who take cardio-active drugs (such as for hypertension, asthma, stimulants etc.)

## Coronary Artery Disease



The heart receives its own blood supply from the coronary arteries. Its requirement for blood increases when it has to perform more work, for example during exercise. For a given level of exercise the heart has to work even harder if the blood pressure is elevated, or if the heart has to beat too rapidly, or if the resistance to blood flow is increased. Arrhythmias also increase the cardiac workload.

**Fig.35.1**

The heart is less able to cope with extra demands for work if the coronary arteries are obstructed, since the blood flow to the heart is reduced. When the coronary arteries do not supply sufficient blood and oxygen to the heart muscles, the latter becomes painful and produces central or left sided chest pain ("angina") or breathlessness (dyspnoea). This may be temporarily remedied by reducing the exercise and the demand for oxygen, by resting. If this deprivation of oxygen to the heart muscle is severe enough, heart muscle dies, and this is then called a myocardial infarction ("heart attack"). In divers, the first sign of this may be at autopsy.

## Heart Muscle Disease

Some forms of heart muscle disease (cardiomyopathy – hereditary, alcoholic, or toxic) may affect its function and can occur at all ages. In non-divers who become aware of these diseases, heart transplants are often the only successful treatments. Divers may be unaware that they have these diseases. Viral infections sometimes involve the heart muscle (myocarditis), often without the patient being aware of this, and these infections predispose to cardiac deaths.

## CONTRIBUTING CAUSES

There are a number of ways death or incapacity from cardiac diseases can come about and they are usually precipitated by one or more **trigger factors** encountered while diving. Some of these are:

### Exercise

Severe exercise can cause sudden death by a number of mechanisms. Probably the most well known example was the death of the first marathon runner who dropped dead after running from Marathon to Athens to deliver the news of the Greek victory over the Persians. In reality, his death was probably due to heat stroke or heat exhaustion. Usually exercise will cause cardiac deaths only in those with some cardiac disease or malfunction.

A diver is at a disadvantage in some ways during exercise. During exertion on land, the cardiac output increases to meet the metabolic demands of the exercising muscles. In doing this, the work of the heart is made easier by blood vessel dilatation in the peripheral circulation, reducing the resistance to blood flow. In an exercising diver however, the skin blood vessels do not dilate because they are trying to conserve heat in response to the surrounding cold water. The diver's heart has to pump against an increased resistance and so work harder for a given amount of exercise, compared to a land athlete.

One of the limitations to exercise on land is the inability to disperse the metabolic heat of exercise. With the diver, much of this heat is conducted away by the water. As a result, it is possible to exercise in the water to a greater degree without the "hot and sweaty" discomfort.

It is therefore possible to exercise to a great degree in the water, with less discomfort but at a greater strain on the heart. In a trained athlete with a healthy heart this probably is only of academic interest. In a middle aged (i.e. over 40 years) diver with some degree of coronary artery disease ("narrowing of the arteries") the diver can overload the heart without realising it. This can result in sudden death.

Exercise, even in fit healthy divers, has been shown to cause significant arrhythmias with diving. It is much more likely to cause incapacitating or fatal arrhythmias in divers with cardiac disease.

### Psychological and Personality Factors

Some personalities are more susceptible to cardiac disease than others. The so called **Type A** or **Type D personality** is believed to be most prone to cardiac disease. These individuals are intensely competitive, aggressive and as a result, by society standards, usually successful. They drive themselves hard and do not give up. They are twice as likely to develop coronary artery disease than others, and when they develop it they are likely to push their diseased heart beyond its limitations.

Traditionally this has been a **male personality trait**, but in a more competitive and equal society it is probable that a similar disease pattern will emerge in women competing in previously male dominated areas. Sudden death is not uncommon in Type A personalities.

**Anxiety** can have threatening cardiac consequences. Anxiety typically causes internal release of adrenalin, one of the stress hormones, which stimulates the heart to contract more forcefully, beat faster, and makes it more prone to arrhythmias. A fast beating heart has less time to replenish its own blood supply and becomes relatively starved of blood.

In the peripheral circulation, adrenalin causes constriction of blood vessels to the skin and internal organs, increasing the resistance to blood flow and the work of the heart. The stressed anxious individual thus has a fast beating heart with a poor blood supply which is more prone to arrhythmias and which has to work harder for a given exercise load.

A condition analogous to fainting (known as **vasovagal syncope**) is commonly seen in individually threatening situations such as a blood donation or the receiving of injections. A nervous response through central stimulation of the vagus nerve causes profound slowing of the heart. The end result is inadequate blood pressure and reduced cerebral circulation causing the diver to lose consciousness (“faint”).

## Cold

Sudden incapacity and death of divers soon after entering cold water has been frequently reported. The body has several immediate responses to cold water which could explain this.

During **cold water immersion** there is an increased sympathetic nervous system activity resulting in the release of adrenalin. This causes the potentially deleterious cardiac effects described above. A greater sympathetic response has been described in individuals who are **not adapted** to cold water exposure **or** who are **unfit**.

Sudden death from **vagal stimulation** associated with the **diving reflex** can occur after immersion of the face in cold water, although it can also be produced by immersion of the trunk in cold water. See below.

Sudden immersion in cold water is thought to be associated with a sudden death syndrome associated with reflex **coronary artery spasm, fatal arrhythmias** or **myocardial infarction**.

Divers will be familiar with the involuntary over breathing which can accompany sudden immersion in cold water or even a cold shower. In experimental animals, and also in man, the heart becomes more prone to arrhythmias caused by the reduction in blood carbon dioxide from this **involuntary hyperventilation**.

**Hypothermia** also makes the heart more prone to arrhythmias and may combine with some of the other problems mentioned above to cause sudden death.

## Reflexes Associated with Diving

### □ The Diving Reflex.

Diving mammals such as whales are able to hold their breath for an hour and attain amazing depths. They are able to do this partly because of the evolution of the dive reflex. When the mammal leaves the surface there is a profound stimulus of the vagus nerve which slows the heart to about a fifth of its normal rate. At the same time, there is intense constriction of the blood supply to the skin and most organs with the exception of the heart, lungs and brain. This conserves oxygen reserves for use by the organs which need it most. The diving mammal maintains a normal blood pressure, but the output and work of the heart is dramatically reduced.

This reflex is present to some extent in humans. When a human is immersed in cold water there is vagal stimulation which slows the heart, as well as sympathetic nervous stimulation which constricts blood vessels to the skin and other organs. Because the reflex is only incompletely developed in man, there is often a rise in blood pressure but minimal or no fall in cardiac output. This increases, rather than reduces, the work of the heart.

The result of this process in man is increased work of the heart as well as the development of cardiac arrhythmias. Studies conducted on the traditional breath-hold Ama who showed an incidence of arrhythmias of 43% in summer, and an even higher incidence in winter.

### ❑ Carotid Sinus Syndrome.

The Carotid arteries, on each side of the neck, are the main arteries which supply the brain with blood, and these have a pressure sensing organ – the carotid sinus – in their walls at about the level of the larynx. External pressure on these carotid sinuses causes the cardiac control centre of the brain to mistakenly assume that the blood pressure has suddenly risen. This leads to a **reflex slowing of the heart** and **reduced blood pressure**. This can cause faintness or even loss of consciousness.

A similar effect is caused by pressure from the collar of a tight fitting wetsuit or dry suit neck seal, on the carotid sinus. The problem is especially likely in wet suits without a front zip fastener or having tight "crew necks".

In a series of 100 carefully documented diving deaths in Australia, only one case was thought to be due to this carotid sinus syndrome. In other cases however, distressed divers were seen to pull a constricting wetsuit away from the neck. This may have been a response to respiratory difficulty from cardiac causes, a tight neck opening in the suit, or the carotid sinus syndrome.

## Hyperbaric Exposure

Studies in experimental subjects breathing air at pressures similar to those experienced by sports divers showed a significant incidence of arrhythmias caused by the hyperbaric exposure. This may be partly due to the elevated partial pressures of oxygen breathed at these depths.

## Immersion

Simply immersing the body in water causes an increased return of blood to the heart, due to the change from a gravity influenced circulation to weightlessness. This rush of blood to the heart can rapidly double its workload until stability is returned. In redistributing blood from the periphery to the lungs, there may be a predisposition to pulmonary oedema (see Chapter 32)

With immersion, the effect of gravity on the blood vessels is removed. Sudden exposure to a gravity effect on the blood vessels, such as climbing up the ladder and out of the water, increases the possibility of hypotensive syncope. This is a good reason to not hover underneath divers on ladders.

## Aspiration

**Aspiration of seawater** – always a possibility in diving – can cause immediate cardiac effects by a mechanism akin to the diving reflex (see above), It can also be followed by delayed effects due to hypoxia as the lungs are involved, as in the salt water aspiration syndrome (see Chapter 26).

## Drug Effects

A large variety of drugs have arrhythmic and other effects on the heart, which may predispose to sudden death. Many can be purchased 'over-the-counter' in pharmacies or supermarkets. Some are contained in 'cold cures' and 'cough mixtures' and may be inadvertently used by divers. Some of these drugs include:

- Alcohol
- Nicotine – cigarette smoking
- Caffeine – coffee and tea, stimulant drugs to overcome sleepiness
- "Social" drugs such as cocaine, weight reducing and stimulant drugs such as amphetamines
- Blood pressure controlling drugs (e.g. calcium channel blockers, beta blockers)
- Drugs used to suppress arrhythmias (e.g. beta blockers)
- Drugs that change electrolyte concentrations in the blood – diuretics and electrolytes
- Sympathomimetic drugs (e.g. decongestants such as pseudoephedrine, anti-asthma medications such as salbutamol, and some anti-seasick drugs).
- Others that may cause arrhythmias –antidepressants, digoxin, some anti-malarials, local anaesthetics.

## Cardiac Disease

### ❑ Coronary artery disease or CAD.

This heart disease (causing narrowing or obstruction of the coronary arteries), while considered to be a disease of middle and older age, is probably present to some degree even in some young adults.

It would appear from post-mortem studies done during the Korean and Vietnam wars that coronary artery disease begins in early adulthood, but usually only causes symptoms and death from heart attack after 40 years of age. The older the diver, the more significant this is likely to be. Divers with this disease are more prone to sudden death due to arrhythmias or myocardial infarction secondary to impaired blood supply to the heart muscle.

### ❑ Coronary artery bypass grafts.

Some blockages of the coronary arteries can be bypassed by blood vessel grafts – usually using arteries or veins. This reduces cardiac pain and improves cardiac performance but does not cure the underlying disease, which affects the many coronary arteries not improved with the by-pass. People with such grafts are still more prone to arrhythmias and cardiac dysfunction and should not dive, unless proven to be cured. A similar situation exists in those people who have already suffered a myocardial infarction or "heart attack" and those needing or possessing pacemakers

## □ Myocarditis.

Some viral infections which produce a flu-like illness can temporarily affect the heart muscle, impairing its performance and making it susceptible to arrhythmias. Sudden deaths from this often insidious condition (myocarditis) are occasionally reported in very fit athletes and in divers. It is unwise to dive or perform heavy exertion when suffering from a viral infection, for this reason.

Sometimes the heart is permanently and irreversibly damaged by such viruses. It is then similar to a cardiomyopathy. In terminal cases the only effective treatment is a heart transplant.

## PREVENTION

All candidates should be carefully examined by an experienced diving physician before dive training. Those with known cardiac disease or a tendency to arrhythmias cannot dive safely. Middle aged divers, and those with high coronary risk factors need regular assessments.

**Coronary risk factors** include:

- a family history of heart disease at a similar age to the diver
- cigarette smoking
- hypertension
  - cardio-active drugs (see earlier)
- obesity
- high cholesterol – hyperlipidaemia
- physical unfitness
- diseases such as diabetes and alcoholism.

Diving situations often require extreme physical exertion, which stresses the heart. A high standard of physical fitness brought about by regular exercise will improve the hearts ability to cope with this exertion.

While jumping into cold water gets the discomfort over quickly, it maximises the physiological stress. Enter cold water slowly to minimise these physiological stresses.

The combination of performance anxiety, transport stress, inadequate sleep, excessive alcohol, coffee and other drugs which often accompany a "high-living" diving holiday may be possible contributors to cardiac arrhythmias, and some deaths in divers.