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IMMEDIATE MANAGEMENT OF DIVING EMERGENCIES

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Underwater activities are undoubtedly one of the growth sports of the 20th century. Such activities, in the well-trained person, are remarkably safe. The majority of casualties are due to trauma or poor seamanship. However, there are a few hazards peculiar to underwater activities which are unfamiliar to the average doctor. The dangers will not decrease and the mere fact that one does not work at a coastal site does not mean that one will not see the results. The amateur SCUBA (Self Contained Underwater Breathing Apparatus) diver uses compressed air delivered to him by a valve system that supplies air at the same pressure as his surroundings. As pressure increases by 1 atmosphere for every 10 metres one descends in water, it can be seen that the deeper one goes the greater the pressure of the gas respired. Thus the partial pressures of the air components in the alveoli are increased and more gas diffuses into the circulation and thus to the tissues. When the pressure is reduced by ascending, this process is reversed. However, if the ascent is too rapid or the volume of gas taken up by the circulation is too large, bubbles will form in the blood and tissues and these will increase in size as more gas diffuse into them. This is the mechanism behind the first of the conditions that must be considered (Brit. Subaqua Manual).

DECOMPRESSION SICKNESS (THE BENDS)

History

The patient will have carried out either one very deep dive (more than 30 metres) or have carried out a

shallower dive for a longer period than is desirable, or multiple dives. With few exceptions he will either not have followed any decompression schedule or will have carried it out inadequately. However, he will almost invariably claim that he has behaved safely. One must not take his word. Decompression tables are not completely foolproof, so it is possible though rare that even if he has dived within their limits he may still develop a bend.

Symptoms

These can be delayed for many hours (up to 24) and are usually considered in two groups, Type I and Type II.

Type I

Pain — is the most common symptom, being present in 90% of all cases of decompression sickness. It often starts as fleeting pains in the limbs (known as "niggles") and progresses as a slowly developing deep ache in or near a joint. It may be preceded by tenderness or numbness in the area and there may be pallor of overlying skin. This severe joint pain is what divers call "the Bends".

Cutaneous Manifestation — a mottled eruption on the upper trunk accompanied by a burning pain, a "cutaneous bend". In itself it is not serious and fades in a few hours, but it can be a precursor of much worse to come, so any patient who develops it should be observed closely.

Type II

The onset of this type of bend is often more vague epigastric pain, headache, angina, vertigo or actual signs of organic malfunction. However, they are mostly central nervous system or pulmonary effects.

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CNS Effects

This is quite rare, about 5% of decompression sickness, and is usually caused by grossly inadequate decompression from a considerable depth. The symptom may be mild dizziness, transient deafness or visual disturbances but can range to para or tetraplegia, unconsciousness, convulsions and death. Immediate decompression is mandatory if permanent sequelae are to be avoided.

Chest

Acute shortness of breath, retrosternal pain especially on inspiration and coughing, may herald collapse, shock and asphyxia. With the increasing dyspnoea the pulse, at first rapid, becomes feeble and increasing cyanosis leads to unconsciousness and death supervenes. This may well occur in conjunction with other symptoms and is probably due to virtually complete blockage of pulmonary capillaries with gas bubbles. It could be confused in the early stages with a myocardial infarction. The treatment is immediate recompression. Fortunately such a disastrous picture occurs in only about 2% of cases (Miles and Mackay, 1976).

The other troubles which occur in divers are of a mechanical nature and affect the ears and sinuses.

Ears and Sinuses

Pain in the sinuses on descent or a small epistaxis at the end of a dive are very common, especially in the first dives of a season. However, more severe ear damage can be caused. As one descends the external pressure on the tympanic membrane increases and it becomes stretched. Insufflating the Eustachian tubes by swallowing or blowing gently against the pinched nose will clear this pressure. If it does not and the person continues to dive ignoring the pain in the ears, the tympanic membrane will rupture, allowing water (usually very cold around the British Isles) to enter the middle ear, causing vertigo, tinnitus and nausea. The person usually returns to the surface immediately. Excessively vigorous attempts to clear the ears can result in a rupture of the round window which leads to immediate complete deafness on the affected side. This may not be noticed until after surfacing at the end of a dive and could be confused with the start of a Type II bend. Either of these conditions should be referred to an ENT specialist as soon as possible (Strauss, 1979).

Lungs

As was previously explained, SCUBA apparatus supplies breathing air at the same ambient pressure as the surroundings. Therefore if a person takes a breath from an aqualung at depth and then surfaces while holding the breath the gas contained within the lungs will expand as the depth and pressure decreases, (Boyle's Law). As the

stretch receptor reflexes are weak in man the diver will probably not be aware of this effect and as the chest wall has only very limited capacity for expansion the pressure within the lungs will rise. This effect can also occur in a localised segment of lung, if for any reason the bronchus or bronchiole is obstructed, especially if that obstruction is of the "Ball valve" type.

The phenomenon can lead to two possible sequelae both covered under the heading of Pulmonary barotrauma.

1. Pneumothorax

This severe and potentially fatal condition may arise with or without accompanying surgical emphysema. If the diver is ascending from considerable depth the pneumothorax may be of the lesion type. Occasionally however, surgical emphysema may arise in the absence of an obvious pneumothorax. Treatment of the pneumothorax is by closed chest drainage. In the absence of neither conditions, recompression therapy is not necessary.

2. Air Embolism

The cause of this phenomenon is internal damage to the lung structure. The hyperinflation of the alveoli caused by the expansion of the gas produced disruption to the pulmonary micro circulation. However, as the pressure within the thorax increases, venous return is considerably obstructed and cardiac output may fall drastically. Therefore at the time of the damage to the pulmonary capillaries these are largely closed and air does not at this time enter them. However, when the diver reaches the surface, exhales and then inhales (usually forcibly), the large negative intra-thoracic pressure thus causes a massive increase in venous return and therefore a large increase in cardiac output, air will then enter the pulmonary capillaries via the damaged walls and pass in large amounts through the lungs into the left-hand side of the heart and circulation, where it produces havoc. Air embolism of this type is extremely lethal and has produced many fatalities.

History

If available at all, it will be of a person having taken a breath from an aqualung and surfaced while holding the breath, or of exceptionally rapid ascending from considerable depth e.g. in emergency with an inflated life jacket. It should be noted that the person concerned may not have been diving with aqualung equipment, as occasionally a snorkel diver has borrowed a mouth piece from a SCUBA diver and taken a few breaths in order to spend a time submerged. Such a practice is extremely dangerous and is discouraged by all responsible regulatory authorities throughout the world. It should also be noticed that this phenomenon may occur in an ascent

from an extremely shallow depth, as little as 3 metres has been reported, and this is well within the depth of many municipal swimming pools.

Symptoms

These include central or pleuritic chest pain, unconsciousness, convulsions, cyanosis, tachycardia, low blood pressure and subcutaneous emphysema. In massive air embolism the victim may well be removed from the water dead.

Treatment

Check for and relieve pneumothorax if applicable. Immediate recompression will reduce the size of gas bubble and decrease the circulatory obstruction (Strauss, 1979). In all cases of decompression sickness or pulmonary barotrauma the naval medical service at HMS Vernon should be contacted immediately and the doctor should liaise between the experts there and the compression chamber operators at the site. "Vernon" will want certain information e.g. depth of dive, length of dive, number of dives, amount of air in cylinder on entry, amount of air in cylinder on exit, previous diving history, previous medical history, etc. They may recommend that certain drugs and therapies be given to the diver and if this is required then someone must go into the chamber with the victim, unless of course the drugs can be orally administered. The procedure of contacting HMS Vernon will be outlined in detail later.

Other Diseases and Conditions

1. Hypothermia

The water temperature in the coast surrounding the United Kingdom and in inland diving sites with the United Kingdom is always low and therefore the diver must be protected against cold. For example, in February at Stoney Cove (a popular inland diving site near Leicester), the water temperature will be around 4°C. Such a temperature would produce rapid unconsciousness and death for the unprotected swimmer, therefore the provision of adequate thermal protection for divers is essential. The time honoured garb for SCUBA activity is a wet suit. This is made from neoprene and works by trapping a thin layer of water between the inside of the suit and the diver's body. This is rapidly warmed by the diver's body heat and produces a warm water envelope for the diver to swim in. At the same time the neoprene foam of which the suit is made produces good insulation from the water outside. Therefore, when diving in the United Kingdom, it is recommended that suits should have a minimum thickness of 6 mm and it should be noted that the deeper one goes the thinner one's suit becomes, as external pressure squashes the air bubbles in the neoprene foam therefore at depth wet suits are much less efficient.

Recently dry suits have reappeared on the market for amateur divers. As the name suggests these are designed to exclude water completely and the amount of thermal protection provided depends on the under clothing worn by the diver and the insulating properties of the suit material. Dry suits are in rubberised canvas from Neoprene, and obviously with this type of suit, one requires less in the way of undergarments than one does if one has one of the suits which are made out of sheet rubberised fabric. However, the latter have advantages in terms of cost, durability and because they have fewer buoyancy problems than the Neoprene Dry suit.

Hypothermia is an insidious condition, because, it creeps up on the diver without him being aware of it; falls at as little as 2°C in core temperature, produces serious impairment of mental capacity, and falls much lower than this may produce serious impairment of physical performance. Therefore, the cold diver is more likely to get into difficulties and he will probably be less able to get out of trouble. Hypothermia could well be the cause of the few unexplained "drownings" that have occurred to SCUBA divers over the years. It should be noted however, that these problems are not confined to the North Atlantic deep waters, even in apparently tropical areas, for example the Red Sea, it is recommended that at least light-weight thermal protection be worn.

Diagnosis

This is usually not difficult to recognise. However shivering, extreme mental and physical sluggishness and indeed unconsciousness may occur. It should also be noted that especially when diving from small open boats, the diver will continue to lose heat even after he has come out of the water. Indeed, most of the thermal effect of the wet suit is lost when out of water and especially if there are cold winds, the diver is in serious danger.

Various preventative measures can be applied, the main one of which is the avoidance of alcohol before diving. Alcohol by producing cutaneous vasodilatation, increases the heat loss. Furthermore, alcohol should not be given to the cold diver as this will cause further falls in his body temperature. The cold diver should be protected from further cooling and from the effects of wind. This is best done in a small open boat, by putting him into a survival bag. This is nothing more than a large plastic bag, and they are widely available at minimal cost from shops which sell mountaineering and camping equipment. The cold diver should be moved as rapidly as possible to a warm shelter, and if very cold should be placed as soon as possible in a warm bath. However, the water temperature should not be too high, not greater than 42°C to avoid scalding. On no account

should alcohol or other vaso-dilator drugs be given. Any diver who is removed from the water unconscious or becomes unconscious should be re-warmed under controlled conditions in hospital. Cardio respiratory arrest can occur, the diver should continue to be resuscitated until the body temperature has been restored to normal levels, because only then can one adequately diagnose death. All these considerations are even more important in children and persons of small stature, as they cool relatively more quickly than the average large male adult. Females are somewhat less prone to hypothermia due to their higher proportion of subcutaneous fat.

Fit To Dive?

The practitioner will occasionally be approached by patients who wish to consult him as to their fitness to undertake SCUBA diving activities.

If such an approach occurs in respect of the British Subaqua Club which has compulsory medical examinations, both on entrance and at regular intervals afterwards, the patient will bring the provided form, on which the details of the examination can be recorded. However in the absence of this a few words on fitness are not out of place. Firstly, divers need not be supermen, relatively modest levels of physical performance are all that is usually required. Certain diseases however are absolute disqualifications to SCUBA diving: These are;

- Epilepsy in all forms
- Diabetes in all forms
- Hypotension, or previous history of ischaemic heart disease
- Severe asthma or chronic obstructive airways disease
- Serious physical impairment or disabilities

It should be noted however, that under closely supervised conditions people with serious physical disability have been able to enjoy underwater activities.

Persons on chronic medication for psychiatric conditions should not dive while taking their drugs. Persons with a history of claustrophobia should be given some practical tests in a comparatively safe environment before undertaking underwater activities. People with certain ENT disorders, especially those concerned with the tympanic membranes and eustachian tubes, should if necessary be referred to an ENT Surgeon. All persons should have a chest X-ray examination before starting a diving career and any evidence of lung cysts or bullae, automatically disqualify from diving. Persons who have undergone pulmonary surgery should be referred for a further opinion, and anybody who has had a history of spontaneous pneumothorax, no matter how well treated, should never dive.

Pregnancy

Women who are in the first 2 trimesters of pregnancy should limit their diving activities to less than 20 metres and to "no stop" dive times. After this time they will probably be unable to undertake underwater activities.

As far as is known, the contraceptive pill does not constitute a hazard in diving. With modern sanitary aids, menstruation also does not seem to cause any problems.

ACTION TO BE TAKEN

Procedure for Contacting HMS Vernon

1. Contact HM Naval Base Portsmouth by telephoning Portsmouth (0705) 22351. In case of difficulty contact GPO operator by dialling 100. State that you are handling a diving emergency and require a priority line to HM Naval Base Portsmouth. Give the GPO operator the number from which you are speaking.
 2. When in contact with HM Naval Base switchboard, repeat that you are handling a diving emergency and ask to be put in contact with HMS Vernon.
 - (a) Business hours — extension 872375 and ask for the "Superintendent of Diving".
 - (b) At all other times — extensions 872413/4 or 5 and ask for the "Duty Lieutenant Commander".
- Give HMS Vernon the number from which you are speaking and your exact location.

The GPO and Naval Base switchboard should remain on the line while connection is made.

Procedure if a diver is brought to an Accident and Emergency Department

1. All necessary resuscitation — give high dose O₂. Establish an intravenous line. Give dextran 70 in saline or dextrose 500 mls 6 hourly in a serious or neurological decompression sickness. Give *NO* analgesics except aspirin. If cerebral symptoms occur, give dexamethasone 12 mg stat followed by 8-10 mg, 6 hourly, reducing over 1-2 days. Consider using Manitol. If paraplegia or tetraplegia is present, catheterise the bladder. *DO NOT* give Nitrous Oxide or Entonox as N₂O may diffuse into bubbles and make them bigger. Diazepam may be used for convulsions.
2. Contact HMS Vernon without delay (as above).
3. Collect and provide necessary information, medical and diving.
4. Prepare to transport to Recompression Chamber.
5. Consider best method of transportation (usually road. If by air as low as reasonably possible).

6. During transportation, position recommended is head down, left lateral position. Continue therapy as 1 above. Take all drugs and equipment as described below.
7. On arrival at Chamber, re-establish contact with Vernon. Place patient in chamber. If attendant is necessary, he must be warmly covered, in good health, without coryza or sinusitis, and must not suffer from claustrophobia. The doctor should not enter chamber himself except in dire emergency as he is better employed liaising with HMS Vernon.

Procedure if called to a Diving Operation Scene

1. Equipment

- (a) Airway maintenance — airways, endotracheal tubes (NB: in the chamber do not inflate cuffs on tubes with air, use water).
- (b) IV equipment, if possible, plastic bags or poly-fusiors.
- (c) Blankets and warm clothing — space blankets are very good — patient may have hypothermia.
- (d) Chest drains with Heimlich valves or (less efficient) underwater seals.
- (e) Examination equipment, stethoscope, BP recording oscillotonometer which is better than an ordinary sphygmomanometer because auscultation is difficult in chamber. Auroscope, ophthalmoscope, basic CNS examination equipment. Low reading thermometer, torch, coloured pins.
- (f) Portable defibrillator with display screen — must be battery operated, but they are not suitable for use in compression chambers for electrical safety reasons.
- (g) Cut down set and sutures.
- (h) Adhesive tapes.
- (i) Charts TPR, BP and NEURO observation.

2. Drugs

An arrest box (preferably 2) 8.4% NaHCO₃ Aspirin, Dexamethasone, Dextran 70 (for plasma expansion

and anti-clotting properties), Manitol, Diazepam (oral and intravenous). Local anaesthetics (2% plain Lignocaine), Heparin (may be requested by HMS Vernon). N.B: No opiates to be given except if especially advised to do so by HMS Vernon.

On arrival if patient is not in chamber, thorough history and examination or if necessary resuscitation should be carried out. If decompression sickness or air embolus are possible (not probable) contact HMS Vernon.

Good notes and records should be kept as treatment may well take from 6 to 22 hours. The person who enters chamber will not be able to leave until the patient does and should not return to duty for at least 24 hours.

Space is at a minimum in the chamber and only essential personnel should be in the chamber room. Liaise with Police if necessary to control onlookers, etc.

Finally, the doctors should not interfere with the work of the chamber operators. They know what they are doing, you don't.

Further Readings

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ACKNOWLEDGEMENTS

Our thanks are due to Surgeon Commander Pearson for his valuable advice in preparation of this article and Mrs. S. Kotecha for typing it.

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