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The occasional diving accident

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With over 200 000 certified scuba divers in Canada, even the most remote lake may be host to a scuba diving accident. SCUBA (self-contained underwater breathing apparatus) refers to the gas storage tank and "regulator," which are designed to feed gas to divers at their ambient pressure. It is this breathing of gas mixtures at higher than normal "hyperbaric" pressures that entails a variety of health problems not normally seen by most physicians.

The steps to handling a diving problem are outlined here.

Step 1:
Understand the mechanism of injury

When handling a diving injury it is imperative to understand the mechanism of injury and the resources available to you. In the human body, the fluids are at a pressure equivalent to the surrounding or "ambient" pressure. When diving down to 34 feet of fresh water (equal to 33 feet of salt water) the pressure that surrounds the diver is double the pressure exerted by the atmosphere at the surface. At 68 feet the pressure triples, and so on. When pressure is exerted on gases, they compress. (Fluids transmit pressure but do not change in volume themselves.) A fixed amount of gas subjected to a doubling in the ambient pressure would compress to half of its previous volume and, correspondingly, when the pressure is halved the volume doubles. (You may remember this as "Boyle's Law.") Therefore, a 10-cc bubble of gas in the colon of a diver would compress to 5 cc at a depth of 34 feet of water. Conversely, if the bowel bacteria produce 10 cc of gas while our subject is at 34 feet the bubble would expand to 20 cc as he or she swims to the surface. These volume and pressure

changes may lead to a variety of medical problems — some minor, some potentially fatal.

To obtain assistance with diving-related problems the phone number that is probably most useful for a rural physician is the Diver Accident Network (919 684-8111). This organization will provide a link between the injured diver and the most appropriate hyperbaric facility and can also provide advice or link the physician with someone who can provide medical advice.

Step 2:
Understand gas embolism

The most devastating problem seen with expanding gas volume involves the lungs. The SCUBA apparatus feeds air to the diver at his or her ambient pressure, so a 300-cc breath taken at 34 feet will expand to 600 cc at the surface. Therefore, as a diver surfaces, gas expanding in the lung must exit via the trachea, or it may rupture into the pulmonary vein and from there advance into the left ventricle and into the systemic circulation. This produces a "clot" made of air, which produces a stroke as effectively as any blood clot. This is known as arterial gas embolism (AGE) or air embolism (AE).

Since air embolism is the result of gas rupturing into the systemic circulation the symptoms are virtually always sudden and immediate upon surfacing, as one would see with a thrombus that leaves a damaged heart ventricle and then produces a stroke. Remember that a diver who is unconscious on surfacing has an air embolism until proven otherwise. As with strokes, the victim can survive a small air embolism, but many air embolisms produce very large volumes of air within the systemic circulation, and this will be immediately fatal. The key difference is that in this case the "clot" can be compressed and it can also be rapidly reabsorbed in a recompression chamber, so treatment (discussed below) involves breathing the highest possible concentration of oxygen and immediate transfer to a recompression chamber. Even small embolisms often lead to secondary drowning since the victim will suffer neurological impairment while still underwater. Air rupturing from the lungs can also produce pneumothorax and subcutaneous emphysema, and these signs should be carefully searched for in any serious diving accident.

Step 3:
Understand decompression sickness

The second broad class of serious diving accident also involves the effects of pressure on gases, although more indirectly. The amount of gas that can dissolve in a liquid is proportional to the pressure within the gas and the liquid. The higher the pressure and/or the longer the exposure, the more gas that will be dissolved. (You may remember this as "Dalton's Law.") If the pressure is let out quickly (as when you uncap a bottle of champagne), the gas comes out of solution quickly and bubbles form in the liquid.

If 5 cc of nitrogen (recall that the air we breathe contains 78% nitrogen) can dissolve in the body fluids at the surface, then 15 cc of nitrogen can be dissolved at 68 feet of depth. A diver who has been at 68 feet long enough will have to bring 10 cc of nitrogen out of solution from her or his body fluids as she or he ascends. Bubbles form when this process occurs too quickly.

Decompression sickness (DCS) is the name given to the symptoms and signs produced by air bubbles in a diver who has stayed too deep for too long. The exposure time required to produce DCS at various depths is available from diving tables, which will almost always be available from the diver or his or her companions. Approximately 10% of divers will develop DCS if they go to the limits of allowable exposure. In rough terms, the exposure required to produce symptoms is many hours at 30 feet of depth, or 60 minutes at 60 feet, or 10 minutes at 100 feet.

DCS is distinguished from air embolism in a number of ways. It takes time for the bubbles to come out of solution and for symptoms to occur. Usually there is a delay of 15 minutes or more after surfacing before symptoms commence. Remember that symptoms that occur within the first 10 minutes of surfacing are air embolism until proven otherwise. It is rare for symptoms of DCS to begin later than 12 hours after ascent. DCS usually begins with pain in the joints and difficulty walking (giving the syndrome its popular name of "the bends"), although more severe cases can affect the lungs, producing a choking sensation, or the spinal cord, producing focal neurological deficits. DCS is rarely fatal, but it is very important to recognize and treat it appropriately and quickly in order to avoid long-term neurological problems.

Step 4:
Recognize minor problems, recognize serious ones

Ear and sinus problems are very frequently encountered by scuba divers. As ambient pressure increases, water is pushed in against the eardrum. Recall that

fluids, although themselves not compressible, can transmit increased pressure, so veins and arteries dilate in the body's air spaces and sinuses and will exude plasma or blood, unless counterbalanced by corresponding increases in the air pressure in the body cavities. Excess water pressure may also rupture the eardrum inwards, and water can then rush into the middle ear.

As the diver ascends, the air within the middle ear will expand and if the space is shared by fluid or blood the eardrum may be stretched outwards. Or, if the pressure is high enough the eardrum may rupture outwards, or else blood in the sinuses may be forced into the nasopharynx. The diver may then complain of earache, deafness, vertigo or blood from the nose or ear.

These problems, including a ruptured tympanum, all tend to settle with time and analgesia. Pain usually resolves within 12 hours or so, and a ruptured drum usually heals within 5 days. Antibiotics are not indicated, and as long as the diver is otherwise well, recompression is not necessary.

Treatment of diving accidents

Diving accidents are difficult to treat for non-experienced physicians, and it is highly recommended that physicians obtain expert advice as soon as possible from the Diver Accident Network. Immediate transfer to a recompression chamber is vital in air embolism or DCS.For the rural physician, initial treatment of these two conditions is similar.

The unconscious diver

a. Get expert assistance stat!
b. Begin treatment with the usual A-B-C approach and provide oxygen at the highest concentration possible.
c. Check for pneumothorax and consider carbon monoxide poisoning (from a contaminated air source).
d. Transport the patient from the field supine.
e. The definitive treatment is recompression in a diving chamber along with hyperbaric oxygen.
f. Remember the possibility of hypothermia.

The conscious diver

a. Perform a detailed history, including length of the last dive, depth reached, exact history of dives in the last 72 hours, time of onset of symptoms, presence of joint pain and a physical examination, including careful neurological assessment.
b. Provide oxygen at the highest possible concentration, plus fluids.
c. Obtain advice if symptoms, signs or exposure are significant.

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