A rat model to study decompression sickness after a trimix dive

DEPTH LIMITATIONS FOR DIVING with air as the breathing gas are well established. During the dive, increased ambient pressure generates an increase in both oxygen and nitrogen partial pressures. Central nervous system oxygen toxicity is well documented (8), and to prevent the risk of hyperoxic-induced seizure, oxygen partial pressure has been limited to 1.7 ATA (170 kPa) in French military oxygen divers. Moreover, breathing air under increased atmospheric pressure has been reported to impair mental and physical capabilities, which becomes apparent at 30 meters of seawater (msw) [91 feet of sea water (fsw)]. The effects have been attributed to the nitrogen content of air at elevated pressures and have been called nitrogen narcosis (3). Swapping nitrogen for a nonnarcotic gas such as helium effectively eliminates this narcosis. Moreover, the low density of helium is beneficial because it decreases the work of breathing at high depth. However, there are a number of problems with helium, such as voice distortion, high thermal conductivity, and the storage and expense of the gas. Furthermore, when humans breathing oxygen-helium are exposed to pressures >11 ATA (100 msw; 305 fsw), signs and symptoms of the high-pressure nervous syndrome (HPNS) start to appear (5). They are characterized by tremor, nausea, vertigo, myoclonia, dysmetry, sleep disturbances, and impairment in psychomotor performance. Abnormal EEG waves, including an increase in slow-wave electrical activity (4–6 Hz), are also found. A good way to suppress the HPNS is to add small amounts of a narcotic gas such as nitrogen (4) to the mixture of helium and oxygen. A trimix of oxygen, helium, and nitrogen has been used successfully by professional divers during very deep saturation dives in a hyperbaric chamber (5).

In view of the problems associated with oxygen toxicity, nitrogen narcosis, and decompression sickness (DCS), the maximum safe limit for breathing air during an open-sea self-contained underwater breathing apparatus (scuba) dive is 60 msw (183 fsw) in France. To extend the maximum safe depth of diving, the oxygen and the nitrogen must both be reduced. Helium breathing effectively overcomes these problems. Consequently, the use of trimix (oxygen, helium, and nitrogen) is of value for scuba divers below 50–60 msw. French military divers use trimix to depths in the 55- to 80-msw (168–244 fsw) range. Technical trimix diving techniques have now been adopted by scientific and archeological divers. This new form of diving began to be used in the recreational diving community in the late 1980s. Although trimix is used during recreational scuba dives, few studies have been conducted on this topic, and there are no readily available decompression tables for these mixtures. The decompression risks and the hyperbaric treatment in the event of a decompression accident after a trimix dive have been little investigated. Probabilistic models have been used to predict DCS in humans. Use of animal data offers the potential to improve this prediction. In this issue of the Journal of Applied Physiology, Arieli and colleagues (1) provide a rat model for DCS following a trimix dive.

The use of a rat model to assess DCS risk in humans is debatable. Although the kinetic similarity of DCS has been demonstrated between humans and large animals such as the sheep, goat, or pig (2, 7), small animals do not appear to adequately reproduce the human observations (7). In their study, Arieli and colleagues (1) found that rats weighing <200 g were highly resistant to DCS. On the other hand, sensitivity increased linearly between 250 and 350 g. This rat population was selected for the experimental model.

The hyperbaric protocol selected by Arieli and colleagues (1) consisted of exposure to an ambient pressure to 1,110 kPa during 30 min with a decompression rate of 100 kPa/min. This exposure induced ~50% DCS + death among rats with a body mass in the range of 250–350 g. In some rats, neurological impairment, including limb paralysis, walking difficulties, or convulsions, was noted. However, in contrast to humans, no permanent disability was observed, suggesting that their responses to DCS stress were not identical.

On the other hand, certain findings of other experimental or human studies were reproduced by the authors in their rat model. A reduction in the susceptibility to DCS was observed in the rats after repeated hyperbaric exposure. In a recent study using a rabbit model, Su and colleagues (12) have shown that a DCS preconditioning reduced the neurological impairment caused by subsequent rapid decompression from exposure to high pressure. The protective effects could be derived from a stress response with an expression of heat shock protein in various tissues. This diving acclimatization has been suggested to occur in humans; indeed, divers undergoing repeated compression-decompression cycles have a reduced susceptibility to acute DCS (9).

A first application of their rat model was used by Arieli and colleagues (1) to compare various hyperbaric protocols. No superiority of a heliox table over an oxygen table was observed. Consistent with human pathology, the earlier the hyperbaric oxygen (HBO) therapy was performed after the decompression the more efficacious it was. Indeed, the importance of an early HBO therapy has been stressed in DCS and in patient victims of iatrogenic venous gas emboli (6, 11). Consequently, some relevant information might be derived from the rat model of Arieli and colleagues.

The study of Arieli and colleagues (1) is an interesting attempt to improve the safety of trimix technical diving from a small animal model. Further studies are needed on this topic.

REFERENCES


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