Physiology and Physics of Helium

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Tissue solubility

Helium enters tissues rapidly, up to 2.65 times faster than nitrogen, and leaves them more rapidly also. This requires the diver to use a different decompression profile with decompression stops starting deeper than for air, with short stops at depth to cope with the rapid onset of offgassing. Helium decompressions can be reduced by the use of nitrox at shallower depths, and can be further reduced by mixing helium with nitrogen to gain the best advantages of both gases where divers are shorter than about 2 hours.

Main effects of Helium

The best known effect of helium is its distortion of speech. The thinner gas passing across the vocal cords at atmospheric pressure produces a comical high-pitched squeak reminiscent of Donald Duck and family. In fact, any change of air density can produce a similar effect - divers at a pressure of 4 bars in a recompression chamber (the equivalent of 30m while diving on air) will produce distorted speech also. Helium's speech distortion is only relevant when through-water communications are being used, and descramblers are commercially available to translate this distorted speech (usually unsuccessfully).

There is an apparent chilling during breathing. This is again due to the thinner molecular density of the gas, which transmits heat more readily by direct conduction that does air. The gas entering the diver's lungs will be colder than air, having lost heat during the journey from the cylinder via the regulator. However, the gas leaving the lungs will not conduct heat out of the body as readily as air, there being fewer molecules to warm up. Air by comparison is denser and may feel warmer when inhaled at any given depth, but will transmit more heat out from the lungs (and thereby contribute more significantly to core heat loss) than helium mixtures.

Where helium based mixtures do contribute significantly to heat loss is when they are used as drysuit inflation gases., but in general the use of trimix or heliox in drysuit inflation is to be avoided at all times.

High pressure nervous syndrome (HPNS) is possibly the most significant limitation to the use of helium as a diving gas, though the physiological process that creates this syndrome is currently still not entirely understood.

HPNS

High Pressure Nervous Syndrome is a physical manifestation of a high pressure gas gradient across tissue compartments, possibly compounded by helium breathing. It is exacerbated by rapid pressurization to depths of over 120 meters and appears at depths of between 120 and 200 meters (400-650'), depending on the speed of descent and, to a degree, the physiology of the diver. Some divers, for reasons not fully understood, appear to be more prone to HPNS than others.

The symptoms of HPNS include muscle tremors, drowsiness, loss of appetite, nausea, dizziness, vertigo, difficulty in concentrating, and visual disturbances, such as spots or patterns breaking up the diver's field of vision. Some of these symptoms are common to several forms of gas toxicity or physiological stressors (e.g. dizziness, nausea, loss of concentration) and could be confused with nitrogen or oxygen toxicity.

In commercial diving, the effects of HPNS are reduced by slow and staged pressurization, and by adding small amounts of nitrogen to "relax" tissues. Divers are pressurized to approximately 10-11 bars (90-100 meters) and held there for several hours for tissue saturation to take place, and the gas gradient to equilibrate. Pressurization is then resumed, and the dive halted again after a further increase in pressure, for the process to repeat itself. The transit to the "bottom" may thus take many hours, far longer than is possible on open or closed circuit SCUBA, with an attendant decompression lasting several days due to the complete saturation of the divers' tissues with the inert gas mixtures involved.

To reduce the effects of HPNS, small amounts of nitrogen may be used in the mixture to "relax" different tissues compartments and so reduce certain of the side effects, notably the muscle tremors that are typically the earliest and least controllable of the effects. The tremors are postulated to be caused by differential dissolution of gases into the tissues of the myelin sheath surrounding the nerves, causing the nerves to locally spasm.

At depths of up to 120 meters HPNS is unlikely to be a problem, though in general, the greater the depth, the more the chance of the syndrome appearing. On the rare occasions that open-circuit divers have descended to greater depths, trimix containing between 7-11% of nitrogen are thought to have contributed to the partial controlling (though not the elimination) of HPNS.

Gas density

Helium's low molecular density has other practical advantages. The thinner molecular structure of helium-based mixtures produces a better regulator performance at depth by direct comparison with air. The reduced density also makes breathing easier, and may help to flush carbon dioxide out of the lungs. Carbon dioxide has been implicated in deep water blackouts, and an increased partial pressure of CO_2 is dangerous. High levels can be reached in the lungs with increasing depth, by improper breathing and increased gas density affecting regulator performance. Trimix can help reduce (but not eliminate) the problem.

Other inert gases

Helium
With the lowest lipid solubility has the lowest narcotic potential (paradoxically expressed as the highest relative narcotic potency (4.26). Xenon, which has the lowest narcotic potency figure (at 0.039) is actually an anaesthetic at atmospheric pressure, while krypton causes dizziness.

Hydrogen
Hydrogen has been used in extremely deep diving operations in excess of 500 msw (1600'), most successfully in association with helium to create hydroheliox. It has no benefit to open-circuit diving, being explosive when mixed with more than 5% oxygen. This would mean that a travel gas would be required to reach a depth at which 5% oxygen would support life, and then a flushing gas used to remove excess oxygen from the diver. At great depth, and when used with oxygen alone, hydrogen has narcotic effects more similar to similar to LSD, and has been implicated in long term psychological changes in saturation divers involved in some of the tests.

Neon
Neon has some advantages for short duration deep diving, but is too expensive to use as an open circuit breathing gas. It is a denser gas than helium and nitrogen, and diffuses more slowly into tissues than both gases, making it suitable for short deep bounce dives. However, it also emerges from tissues more slowly, and where long exposures are involves, decompressions can be excessive. Neox bends may also be more difficult to treat, involving complex recompression schedules.

Argon
Whilst almost twice as narcotic than nitrogen, it is also denser, and may have some application as a decompression gas. In theory, shallow stops could benefit from argox mixtures, reducing the amount of inert gas counter diffusion into the tissues at depths over 9 meters, though this has had only limited testing, and cannot currently be recommended as a safe practice.

Oxygen and CO_2 narcosis

There is some evidence to suggest that varying partial pressures of oxygen may affect narcosis, with higher partial pressures producing slight anaesthetic effects similar to narcosis.

Carbon dioxide retention may be involved in this, and undoubtedly higher levels of dissolved CO_2 in the blood due to CO_2 retention will affect the behaviour of other dissolved gases to some degree. The relevance of CO_2 to technical diving is primarily to the effect of increased partial pressures of CO_2 causing depth blackout in association with increased workload at depth. The best way to avoid this is by breathing properly and pacing effort during the dive.

Long term effects of deep diving

There are several potential long term effects of deep diving of which the recreational or professional trimix diver should be aware. Many of these are still postulated, and remain formally unproven, but enough evidence exists to suggest that damage may be done to the diver's body by a variety of pressure-related processes.

Capillary Atrophication and Aseptic Bone Necrosis

Perhaps the best known of the long term problems is Aseptic Bone Necrosis, where the destruction of capillaries within bone tissues causes local necrosis of the bone - that is, the bone tissue effectively dies and falls apart. Traditionally, the long bones (thighs, shins, arms) were most at risk, with the heads of joints at shoulder and pelvis especially at risk. At one time this was though to occur primarily in commercial saturation divers, but it has been fairly commonly recorded in recreational divers, where there is some evidence to suggest that it affects the center sections of bones rather than the ends. What causes it is not entirely known, other than it is associated with capillary Atrophication. Such Atrophication may be associated with rapid pressurization and/or depressurization, where different tissues within the bloodstream on and offgas at different rates. This means that certain of the blood's constituent tissues may at different times during descent or ascent act as effective dams within the smallest capillary beds, creating tiny local embolisms or micro-Atrophication. Though this is perhaps most crucial in bones, capillary beds also exist in other vital areas of the body such as the brain, soft tissues such as the liver, kidneys, eyes, etc. At present, alterations to capillary bed structure in these other tissues are best described as "change" rather than damage, until more research is done on both cause and effect.

Research on Aseptic Bone Necrosis shows that affects approximately 5% of divers (both recreational and commercial) to some degree or another. Deep mixed gas diving may be one contributory factor, as may rapid pressurization/ depressurization, but the increase in symptoms evinced in recreational divers who do not undertake such practices suggests that the problem still warrants further research before too many conclusions can be drawn.

Bubble formation

Micro-bubbles forming during decompression, though not creating any formal symptoms of decompression illness, may result in long term CNS damage to the spinal cord. Post-mortems in divers who have not reported any symptoms of DCI during life have still been found to have significant damage to the spinal cord and central nervous system.

Those who have had formal decompression events may have significantly greater long term problems, especially divers who have suffered multiple type II bends.

Such "invisible damage" may or may not be associated with deep diving. It is possible that now out-dated diving practices may have contributed to these (e.g. faster ascent rates) and that individual physiology may also play a part. To a degree, all life activity, above or below water, contributes to the eventual long term decay of the body, and the older we get the more damage has been picked up along the way. It is possible to overreact to physiological "possibilities", and it must also be remembered that diving of any sort has a very low incidence of long term serious physiological damage per individual diver when compared with other activities.

However, when formal damage does occur it should be treated seriously. Getting decompression illness may result in small localized damage or it may contribute to longer term damage, such as possible brain lesions, which may in turn create later problems from reduced mental or physical function to premature senility. Divers of all sorts, and mixed gas divers in particular, should be aware of current research in diving medicine, and should keep themselves up to date with changes in our knowledge and understanding of diving medicine.

Limits

The practical depth limits of mixed gas open circuit diving, taking into account the physiological and environmental limitations of the activity, lie within the following boundaries. Cold water (below 200C) : 75-80 meters. (240-260') Warm water (over 200C) : 100-120 meters. (330-400')

The planning and execution of safe dives to these depths requires considerable knowledge and experience beyond that of the ordinary recreational SCUBA diver, and safe diving to depths in excess of these generally requires one atmosphere systems or saturation diving techniques, with all the massive attendant expense. While the occasional dive on open or closed circuit SCUBA to depths in excess of 120 meters does take place, the individual undertaking it has usually undergone considerable preparation, training and acclimatization, and has considerable support, or is simply very stupid.