Evaluating the Narcotic Potential of Breathing Gasses

The effects of narcosis vary from subtle decrement in judgement to total incapacitation; this reality asserts the importance reducing or more preferably eliminating narcotic impairment. Narcosis can be produced by a very wide variety of species, from simple gases as xenon and nitrogen to complex hydrocarbons used to produce general anesthesia. Although the narcotic effect of gases has been studied for over 100 years, a full understanding of how gases produce narcosis (and anesthesia) is lacking. Much of what is know about the narcotic effect of nitrogen is derived from study of anesthetic gases. Around 1900, Meyer and Overton independently observed that the potencies of general anesthetic gases correlated with solubility of the gas in a simple organic solvent, olive oil. These observations have become known as the Meyer-Overton rule, which predicts that anesthetic potency of a gas is inversely related to lipid solubility. In other words, more lipid soluble gases produce narcotic effects at lower concentrations than less soluble gases. Table 1 lists Bunsen's solubility coefficients for common gasses.

Thus, based on lipid solubility, helium should be the least narcotic and nitrous oxide and xenon the most narcotic gases. The anesthetic potency of these gases in animals and humans closely parallels the lipid solubility. Highly soluble gases as nitrous oxide and xenon can be used as anesthetics at normobaric pressure. Some interesting observations follow from this evaluation of lipid solubility. Notice that oxygen is considered to be twice as soluble as nitrogen, and thus should be twice as narcotic. However, evaluations of oxygen are more complex because this gas is metabolized by the body; the increase in tissue partial pressure of oxygen in one's tissues does is not the same as the increase in inspired oxygen partial pressure. Despite this complexity it is

Gas	Bunsen Solubility Coefficient in Olive Oil, 22°C, ata^{-1}
Helium	0.015
Hydrogen	0.042
Nitrogen	0.052
Oxygen	0.11
Argon	0.15
Krypton	0.44
Carbon Dioxide	1.34
Nitrous Oxide	1.56
Xenon	1.9

Table 1. Bunsen solubility coefficients for common gases.

prudent to assume that oxygen is narcotic. Similarly a review of lipid solubility demonstrates that carbon dioxide is extremely soluble in lipid tissue; as we expect it is also very narcotic. In fact, CO2 is so narcotic that it has been used as an anesthesia in animals. Increased arterial partial pressure of carbon dioxide above 60 mmHg produces narcosis in humans, and arterial pCO_2 greater than 100 to 120 mmHg may result in loss of consciousness.

Because the Meyer-Overton rule is based on lipid solubility, it would lead one to believe that gases exert narcotic effects by dissolving in cell membranes, which are composed of lipids. Consciousness is controlled by the central nervous system (CNS) and alterations of function of the CNS lead to reduction in consciousness. Like all cells, the neurons in the CNS have lipid membranes as well as embedded proteins that serve as ion channels or receptors for extracellular compounds. Lipid soluble gases are proposed to alter neuron function by dissolving in the lipids and interfering with normal cellular function. There are a number of mechanisms by which altering the lipid membrane could interfere with neuron function; this might occur either by directly altering the properties of the lipid membrane, or by indirectly affecting the properties of embedded proteins. When anesthetic gases dissolve in lipid membranes, they disorder the normal closely packed ordering of the lipid molecules, and increase the fluidity of the membrane. In addition, this disordering pushes lipid molecules apart and increases the area of the membrane. The increased area of the membrane may impinge on embedded proteins, interfering with their function.

As good as the Meyer-Overton rule is it fails to predict anesthetic potency of a number of compounds and is likely an incomplete description of actual events within the body. With organic hydrocarbons such as alcohols increasing the chain length of the hydrocarbon increases the lipid solubility and the anesthetic potency; however, this is only valid up to a point. With most series of organic compounds when the chain length reaches 10 to 14 carbon atoms there is a sudden loss of anesthetic effect. Although this compound is lipid soluble it does not produce narcosis. The Meyer-Overton rule cannot explain this sudden loss of anesthetic effect. In addition, molecular isomers (the same atoms, but arranged differently) of clinically utilized anesthetics have identical lipid solubility but different anesthetic potencies. Again, based on the Meyer-Overton rule, they should have identical anesthetic potency. Based on these discrepancies there are likely to be factors involved in anesthetic effect of gases other than lipid solubility. The full complexity of narcosis and general anesthesia is not fully understood; yet, our grasp of the main mechanisms of narcosis and the primary agents responsible seems sufficient toward our making good decisions about the gasses that we breathe while diving. The complexities of the Meyer-Overton rule are not especially relevant given the gasses and depth of our diving, making this rule a useful tool toward reducing narcosis and associated diving risk.

Experimentation with narcotic gasses helps us to resolve important questions relating to the safety of dives. This research, together with the Meyer-Overton rule, helps us to identify safe diving parameters for various gasses; this knowledge also weighs heavily in the selection of GUE standard gasses. This research also helps us to understand that some divers wrongly assume narcosis can be managed through adaptation. Objective measurement of divers using narcotic gasses shows that there is no adaptation in reaction time; there is also no reduction in their tendency to make mistakes while impaired. However, individuals studied do wrongly perceive a reduction of narcosis; although the divers imagined they were less impaired there was no objective evidence that they were less impaired.

Depression of the CNS by illicit drugs, alcohol, and antihistamines may further exacerbate narcosis. Carbon dioxide retention can also exacerbate narcosis; the interaction between carbon dioxide and nitrogen suggests that the two are additive,

notably increasing the total narcotic affect. While one might avoid the use of drugs, carbon dioxide retention may be more complicated. Arterial partial pressure of carbon dioxide may be elevated by a number of factors, including exertion at depth, rebreathing expired CO_2 (i.e., a large dead space in breathing equipment), restrictive suits, and regulators with high breathing resistance.

In summary, one should recognize that our knowledge of narcosis is incomplete. However, the complexity of the issues affecting narcosis encourages the sensible diver to insist upon a conservative approach to the use of narcotic gasses; gas selection at various depths should assume a worst case scenario. These concerns, together with a long history of aggressive diving, form the basis of GUE's standard gasses.

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