"Deep Stop Modeling"

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At DEMA 2000, NAUI Worldwide premiered a new training CD for Mixed Gas Diving, which includes ranged trimix and helitrox decompression tables developed by Bruce Wienke. These tables employ the Reduced Gradient Bubble Model (RGBM) that incorporates tissue halftime compartments ranging from one to 720 minutes for gas mixtures composed of helium, nitrogen and oxygen. However, unlike pure dissolved gas models that assume all inert gas stays in solution, bubble separation and growth is the central focus in RGBM decompression calculations. As such, the model calls for much deeper initial decompression stops and slower ascents to limit micro-bubble formation and evolution. An effect of this is reductions in shallow stop times as well as total decompression times compared to the schedules for identical profiles generated with traditional Haldanian decompression models. Addressing both free phase (bubbles) and dissolved gas phase, their interplay and impact on diving protocols is welcomed news for mixed gas divers!

Is this new? Certainly not! At DEMA 1999, Suunto premiered the VYPER nitrox dive computer that uses RGBM and another manufacturer is working to implement limited RGBM code into its mixed gas computer for no-stop dives. NAUI mixed gas instructors working with NAUI Technical Operations have been using RGBM generated schedules for nitrox, helitrox, heliox, and trimix dives with great success for several years now. Extended range dives have included gas switches during ascent to accelerate stage decompression, but also the use of alternative bailout mixtures as a safety option during mixed gas training dives.

Doppler technology, decompression computer development, theory, statistics, and observations by exploration divers pushing the limits of depth and time have stimulated a safer diving consensus and a new look at algorithms and gas switching. The result has been dramatic changes in diving protocols and table procedures. It’s probably not readily apparent to new divers, but the last decade has witnessed a shift to shorter NDL's, slower ascent rates, discretionary safety stops, more restrictive repetitive profiles, lower critical tensions (M values), and longer flying after diving surface intervals.

Although the face of diving has been transforming all along, change is hard when it flies against conventional thinking. Understanding the basic differences between free-gas phase modeling and dissolved gas modeling should make it clear why NAUI Technical Operations chose to go with the RGBM for mixed gas diving.

No one fully understands the origin, dissolution mechanisms or migration patterns of bubbles, but bubble size, amount (total volume) and growth rates need to be controlled along with the amount of gas remaining in solution.

Biophysical models of inert gas transport and bubble formation all try to prevent decompression illness (DCI), however they differ on a number of basic issues, most of which are still unresolved today.

1)The limiting process for both diffusion and perfusion.

2)The composition and location of the bends sites.

3)The mechanism of bubble formation and growth.

4)The critical trigger point best delimiting the onset of DCI symptoms.

5)The nature of the critical insult causing DCI.

Traditional dissolved gas models limit degrees of tissue saturation and elimination by maximum critical tensions, called M-values. They assume perfusion and diffusion (the two mechanisms of inert gas and oxygen exchange between tissues and blood) are the controlling factors for inert gas elimination. Perfusion refers to the rate of gas delivery via blood, while diffusion refers to gas penetration across tissue-blood boundaries.

For a single bounce dive, dissolved gas models are limited by the saturation of a slow, single compartment, such as the 120-minute half-time for the U.S. Navy Standard Air Decompression tables. For repetitive dives, multiple controlling compartments come into play to gradually decrease no-stop limits and increase desaturation times for staged decompression dives. The key point is that the elimination gradient is maximized as the diver approaches the surface and the model seeks to do this in as short a time as possible.

Gas phase models assume a distribution of seeds (parent media for potential bubbles) is always present and that some number of these seeds will be excited into growth during compression-decompression. Slower and deeper ascent staging seeks to control bubble growth rate and their collective volume. The bubble elimination gradient is maximized with increasing depth, while dissolved gas elimination is maximized with decreasing depth.

Many mixed gas divers appreciate the physiological benefits of deeper stops. But when generating decompression schedules from solution-based desktop decompression software, the addition of deep stops dramatically increases shallow stop times. However, the deeper staging format inherent with bubble models actually reduces shallow stops times.

The RGBM is a dual phase model that couples a weighted split between free-blood and dissolved-blood gradients, with the weighting fraction proportional to the amount of separated gas. Bubble volume constraints control deep stops and blood-flow rate serves as the boundary condition for tissue gas penetration by diffusion for shallow stops. In addition, because body tissues and blood are normally undersaturated with respect to ambient pressures at equilibrium, RGBM considers this debt, called the "Oxygen Window," in its calculations.

RGBM NDLS are tuned to recent Doppler measurements and the added effects of new bubbles reduce bubble volume limit points. This and bubble elimination and buildup during surface intervals, dependent on tracking critical bubble volume reductions over time and the addition of seed bubbles to existing bubbles in calculations, restricts multidiving.

Sources: Naui-Tec

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