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DCS AND DECOMPRESSION THEORY – BASIC PRINCIPLES PART II

In the last two articles we looked at the early history of decompression sickness (DCS) and started to develop some fundamental concepts for decompression and DCS. We showed how absorption and elimination of inert gas from the body follows an exponential curve, and how inert gas delivery to the body is determined by cardiac output. We concluded by showing that fat will contain 4.5 more nitrogen than water at the same partial pressure.

The body is mostly water and in fact all of the tissues of the body have a solubility for nitrogen that is similar to water, except for the fat. The absorption of nitrogen/inert gas by the entire body is determined by the cardiac output as the blood delivers N2 to the tissues. However absorption of nitrogen by a specific tissue depends on the blood flow to that tissue, and the fat content of the tissue.

Adipose tissue has an extremely limited blood flow as it is really just a storage depot (it has limited metabolic activity). Therefore, when we are diving relatively little nitrogen is delivered to our adipose tissue, and fat has a very high capacity to store nitrogen. The net effect is that the pN2 rises very slowly in adipose tissue during a dive (with the same blood flow, a water based tissue will saturate 4.5 times faster than adipose tissue). As a result, adipose tissue is never a factor in the risk of DCS after a single sport dive.

However, adipose tissue eliminates N2 equally slowly and it takes a very long time (1 to 3 days) to eliminate the N2 absorbed during a single dive. Therefore, over a series of dives N2 will build up in the adipose tissue until it becomes a risk factor for DCS. This is one of the reasons experts recommend divers have a "no dive" day every third or fourth day during a diving holiday, and why you have to wait a lot longer before flying after doing a series of dives than after a single dive.

However, when you are diving in cold water, a layer of fat under the skin can be a good thing! When you get cold the body reduces the blood flow to your arms and legs to conserve heat. We usually get cold near the end of a dive and therefore the N2 we absorbed during the dive gets "trapped" in our arms and legs and even if we do the required decompression time, we will surface with a lot more N2 in our arms and legs than calculated by decompression models. This was a major factor when I developed DCS as I was extremely cold during almost 2.5 hours of decompression (drysuit leak).

ALTHOUGH IT IS IMPOSSIBLE TO KNOW THE PARTIAL PRESSURE OF INERT GAS IN A GIVEN TISSUE, IT IS REASONABLE TO ASSUME THAT SOME TISSUES WILL SATURATE FASTER THAN OTHERS

To summarize, fat is important in the risk of decompression from saturation (altitude DCS) and after a series of dives. It is my impression that the increased risk of DCS in a slightly overweight but otherwise physically fit diver is more than offset by the reduction in risk of DCS due to the increased insulation provided by the fat, when diving in cold water.

The water based tissues of the body have highly variable rates of blood flow. Bone has a minimal blood flow. The gastrointestinal tract has a high blood flow when it is digesting food but a greatly reduced blood flow when it is resting or when the person is highly stressed. The "fight or flight" response virtually shuts down the blood flow to the gut and diverts it to the muscles so that the person can fight or run!

The most interesting tissue from a decompression perspective is muscle. Blood flow to a muscle completely at rest is minimal. However, blood flow to a maximally working muscle is up to 100 times greater! Therefore, N2 delivery to muscle tissue will increase up to 100 times with maximal exercise. The significance of this fact on the risk of developing DCS should be self-evident.

As a result of all these factors, the rate of saturation and the pN2 will vary from tissue to tissue during a dive. Haldane developed a brilliant way to address this insane complexity. Although it is impossible to know the partial pressure of inert gas in a given tissue, it is reasonable to assume that some tissues will saturate faster than others. It is also reasonable to group all tissues with similar saturation rates together.

Therefore Haldane proposed that the many tissues of the body could be represented by five different tissue saturation half-time groups (five imaginary groups of tissues). He used a 5-minute half-time for the fastest tissues, a 10 minute half-time for slower tissues, a 20 minute half-time for the next group of tissues, a 40 minute half-time for the next group, and a 75 minute half-time to represent the slowest tissues in the body. The rates at which these tissue groups saturate is shown in the table. It is important to emphasize that these tissue half-time groups are a mathematical concept and that they do not represent specific body tissues. It is also important to remember that Haldane had to do all of the calculations by hand (computers had not been invented).

Using more than 5 tissue groups would have made calculating decompression tables much more difficult. More recent models based on this concept use more tissue groups and tissue half-times out to a few hours. Never forget that these are mathematical models that have no idea what is actually happening in the body.

Critical Supersaturation Ratio Hypothesis
Haldane took some goats (about the same size and temperament as humans) and pressurized them in a chamber over night (assuming that all of their tissues would be saturated by this dive) and returned them to the surface the next day. The goats were usually OK as long as the depth was less than 10 msw (2 ATA) but if the depth was greater, most of the goats developed DCS. Haldane concluded that the body could tolerate being supersaturated with air up to a critical ratio of twice ambient pressure. This is known as the "Critical Supersaturation Ratio Hypothesis" and led to Haldane's third principle, "decompression should be initiated by a relatively large drop in ambient pressure".

Haldane's fourth principle, "tissues can tolerate a certain amount of inert gas

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Tissue half-time	Time to reach indicate % saturation or desaturation (min)					
	50%	75%	87.5%	93.75%	96.88%	98.44%
5	5	10	15	20	25	30
10	10	20	30	40	50	60
20	20	40	60	80	100	120
40	40	80	120	160	200	240
75	75	150	225	300	375	450

Fundamental Concepts for Decompression and DCS

1. The uptake and elimination of inert gas by the body follows an exponential curve.
2. The rate at which inert gas is absorbed into our bodies increases with depth.
3. Nitrogen delivery to tissues is a function of the pN2 we are breathing and our cardiac output.
4. On a hard working or stressful dive, nitrogen will be absorbed into the body at approximately twice the rate assumed by decompression models.
5. Nitrogen is 4.5 times more soluble in fat than in water.
6. Obese people have an increased risk of altitude DCS (decompression from saturation), DCS when flying after diving, and DCS after a series of dives.
7. Mild obesity reduces the risk of DCS when diving in cold water in otherwise fit divers.
8. A maximally working muscle will absorb inert gas up to 100 times faster than a resting muscle.
9. The more decompression time a dive requires, the greater the risk of DCS.

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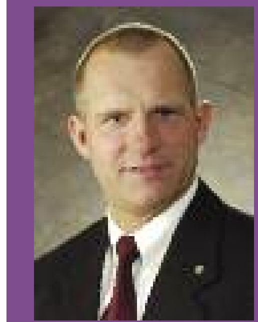

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supersaturation" is a logical result of this observation. Over time we have learned that "fast" tissues can tolerate more supersaturation than "slow" tissues and that longer tissue half-times are required to calculate safe decompression profiles for very long/deep dives and for series of dives.

Decompression profiles are calculated by determining the shallowest depth the diver can ascend to before the pN2 in one of the compartments reaches it's critical level. The diver stops at that depth until enough N2 has left the body (the pN2 in the controlling tissue compartment is reduced) for it to be safe to ascend to the next decompression stop depth. This continues until it is safe for the diver to surface.

Decompression could be continuous but it is broken up into stops at specific depths to make it practical. When a diver surfaces from a decompression dive, they are calculated to have the maximum allowable pN2 in one of the tissue compartments.

If decompression equations were perfect, a diver would have the same risk of developing DCS after every decompression dive and that risk would be the same as a dive right to the no-decompression limit. Unfortunately, no decompression equation is perfect and with the ones currently in use, the more decompression time a dive requires, the greater the risk of DCS.

We have completed our discussion of the basic principles of decompression. In the next column we will explore the commonly accepted risk factors for DCS and try and determine why they might be important. As our understanding of DCS improves, we will be able to plan our dives with minimal risk of DCS.

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