Dr David Sawatzky

Any personal enquiries can be sent to sportdiving@motpub.com.au

ASCENT PROFILES AND THE RISK OF DCS

In the last few columns we looked at the history of decompression sickness (DCS) and developed some fundamental concepts for decompression and DCS. In this column I will look at ascent profiles and the effect they can have on the risk of DCS after a dive. There is limited good data so much of this column is just my personal opinion, based on almost three decades of working in the field and doing technical diving.

For a given dive profile, the less time you spend decompressing the greater the risk of DCS (usually). In general, our risk of developing DCS after a dive is related to the amount of excess inert gas in our bodies when we reach the surface. While we are ascending our bodies are eliminating some of the excess inert gas (nitrogen, helium) we absorbed during the dive. For a given dive profile, as we reduce the time our bodies have to eliminate gas during ascent, the more inert gas there will be in our bodies when we reach the surface.

ASCENT RATES

It is critical to remember that all ascent time is important, not just decompression stop time. Most decompression tables and computers base their calculations on an ascent rate of 9 or 18 metres per minute. Therefore, after a no-D dive to 40 msw a diver should take 4.5 minutes to ascend to the surface at 9 metres per minute (40 msw / 9 metres per minute = 4.5 minutes).

Studies have shown that recreational divers who are trying to ascend at a rate of 18 metres per minute often ascend at rates of up to 60 metres per minute! This rate of ascent would reduce the ascent time from 40 msw to the surface to only 40 seconds (40 msw / 60 metres per minute * 60 seconds = 40 seconds). A diver ascending from 40 msw at this rate would have missed almost four minutes of time during which their body should have been eliminating excess inert gas. Obviously they will have more excess inert gas in their bodies when they surface and their risk of DCS will be greater than if they had ascended at a slower rate.

The importance of ascent rate and ascent time relevant to the risk of DCS, even after no-decompression dives, is emphasized by the fact that most newer decompression models use an ascent rate of 9 or 10 msw per minute rather than the traditional 18 msw per minute. Therefore, in general it seems that slower ascent rates reduce the risk of DCS, certainly for deeper no-decompression dives. In addition, there is some evidence that a 2 to 3 minute stop at 15 msw plus a 2 to 3 min stop at 6 msw results in reduced bubbles scores after a 25 msw for 20-25 min no-decompression dive.

DEEP STOPS

Unfortunately, when you get into dives that require significant amounts of decompression stop time, the situation becomes even less clear. The idea of deep stops has been around for several decades but was brought to prominence in the technical diving community by Richard Pyle, a scientist who studies fish typically found deeper than 50 msw. Many fish have a 'swim bladder'. This is a gas bubble that the fish use to keep themselves neutrally buoyant. When Richard brought fish that he had collected from significant depths to the surface, the gas in the swim bladder expanded according to Boyle's Law and the fish died. He discovered that he had to stop at approximately half of the depth where he had collected the fish and insert a needle into the swim bladder to allow the excess gas to escape.

Over a few years and hundreds of dives, Richard and his dive buddies noticed that on dives where they had to stop for a few minutes to needle the fish, they felt much better after the dive than on dives where they simply ascended according to their dive tables/computers. Fatigue is a well-known warning sign of DCS, so the idea was that doing the 'deep stops' was reducing the risk of DCS. Richard published/presented his observations and the debate about 'deep or Pyle stops' started.

Classical Haldanian decompression theory does not take bubbles into consideration. According to Haldanian theory, you want to ascend from the bottom as quickly as possible, to as shallow as possible to maximize the inert gas supersaturation in the tissues while at the same time keeping the inert gas partial pressure below some limit to avoid DCS. The greater the tissue inert gas supersaturation, the more inert gas will dissolve in the blood and the quicker it will be eliminated from the body. This approach to decompression results in a rapid ascent from the bottom to a relatively shallow first decompression stop and long shallow decompression stops. During the following discussion you must never forget that the classical Haldanian approach to decompression has been proven to work (although it might not be optimal).

According to classical Haldanian theory, doing a deep stop at approximately 1/2 the maximum depth of the dive for a couple of minutes should result in more inert gas being absorbed by the body during the 'deep stop' and therefore more decompression time should be required. The problem is that if the partial pressure of inert gas in the body becomes too much greater than the ambient pressure, the inert gas will come out of solution and form bubbles. If the bubbles form in the veins and are carried back to the lungs, inert gas is removed from the body faster than if the inert gas has to be transported by the blood in solution.

However, if bubbles form in the tissues of the body, when the inert gas moves from being in solution in the tissue to being in a bubble, the partial pressure of inert gas in the tissue will be reduced. This will reduce the amount of inert gas that will dissolve in the blood and will reduce the rate at which inert gas is removed from the body. Therefore, if you form venous bubbles inert gas is eliminated faster while if you form tissue bubbles, inert gas is eliminated much slower.

UNFORTUNATELY, LITTLE GOOD SCIENCE HAS BEEN DONE AND BASICALLY WE DON'T HAVE ANY IDEA WHICH APPROACH OR COMBINATION IS BEST. HOWEVER, EVERYONE PRETTY MUCH AGREES THAT THE IDEA HAS MERIT.

The basic assumption behind deep stops is that typical Haldanian decompression results in the formation of tissue bubbles in fast tissues during the rapid reduction in pressure from the bottom to the first stop. Once tissue bubbles have formed, very long shallow stops are required to eliminate the excess inert gas from the body because of the reduce partial pressure of inert gas in the tissues (no one knows if this assumption is actually true).

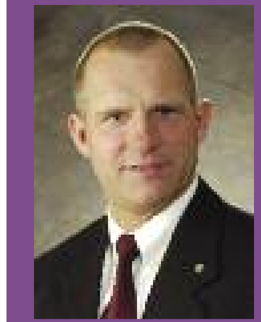
If tissue bubbles do form during the rapid pull to the first stop, a deep stop should allow inert gas to leave the rapid tissues so that tissue bubbles do not form. Without tissue bubbles, inert gas should leave the body much more rapidly during the subsequent decompression stops. However, more inert gas will have been absorbed during the deep stop so more inert gas will need to be eliminated. If the increase in elimination of inert gas is great enough, either the risk of DCS will be dramatically reduced or the time spent at shallow stops could be reduced.

There are several ways to theoretically prevent the formation of these hypothetical tissue bubbles. You could slow your ascent rate down so that the fast tissues could eliminate more inert gas during the ascent to the first stop. You could do a "deep stop". You could do several one-minute stops during the ascent to the first stop (really a slow ascent or several short deep stops). You could make the first stop deeper. Etc. Divers have tried all of these ideas. Unfortunately, little good science has been done and basically we don't have any idea which approach or combination is best. However, everyone pretty much agrees that the idea has merit. How about 'bubble models'? There are several 'bubble' decompression models now available, but none of them has had anywhere near the amount of testing that the 'Haldanian' models have. They tend to have much deeper first stops and shorter shallow stops. Initially total decompression time was less but the incidence of DCS was too high. The models have been adjusted and now total decompression times are similar to Haldanian models.

We will never be able to do enough human research to determine which ascent

>

DAVID SAWATZKY, S.C., C.D., B.Med.Sc., M.D., M.Sc., is a diving medical specialist on contract at Defence Research and Development Toronto from 1998 to 2005. Previously he was the Canadian Forces Staff Officer in Hyperbaric Medicine at DCIEM (1986-1993) and later the Senior Medical Officer at Garrison Support Unit Toronto (1993-1998). He's written a monthly column on diving medicine in Canada's *Diver* Magazine since 1993, has been on the Board of Advisors for the International Association of Nitrox and Technical Divers (IANTD) since 2000, and is an active cave, trimix and closed circuit rebreather diver/instructor/instructor trainer. David's first love is cave diving exploration and he's been exploring and surveying underwater passages in Canada since 1985. David was responsible for the exploration and mapping of almost 11 kilometres of underwater passages in the Ottawa River Cave System. In 1995, he executed the first successful rescue of a missing trained cave diver. David received the Canadian Star of Courage for this rescue which took place in the chilly Canadian waters of Tobermory, Ontario. He still dives as much as possible, but admits his five year old son Lukas, four year old daughter Emeline and wife (Dr Debbie Pestell) are currently higher priorities than diving!



profile is safest using DCS as the end point. However, there is now good evidence linking the quantity of Doppler detected intravascular gas and the risk of DCS (this was the primary topic of my MSc thesis and will be the topic of a future column). Doppler detected bubbles are now used to develop and test decompression models/tables and can be used to try and determine optimal ascent rates and profiles. This type of research is just starting to be conducted.

At the moment, the following conclusions seem to be justified. On deeper dives (50 msw or more) you should ascend fairly rapidly until the partial pressure of inert gas in the fast tissues is at a maximum, safe level of supersaturation (this depth is unknown but could be as little as 10 msw less than the maximum depth of the dive). You should then slow your ascent rate so that the fast tissues can eliminate enough inert gas so that the partial pressure of inert gas in these tissues is maintained constant as you ascend (preventing the formation of tissue bubbles). Finally, you should start your decompression stops a bit deeper than called for by Haldanian models.

Practically this can be approximated by ascending at 9 metres per minute, stopping for one minute every 10 metres, stopping for one minute 6 metres deeper than called for by your computer, stopping for two minutes 3 metres deeper than called for by your computer, and then doing all of the decompression your computer requires (assuming that your computer is using a Haldanian type model). Total decompression time will be slightly increased, but hopefully the risk of DCS will be significantly reduced. Never forget that the only guaranteed way to avoid DCS is to not dive. ■