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THE IMPORTANCE OF DEEP SAFETY STOPS: RETHINKING ASCENT PATTERNS FROM DECOMPRESSION DIVES

Richard Pyle

Key Words

Bubbles, deep diving, mixed gas, tables, technical diving.

Before I begin, let me make something perfectly clear. I am an ichthyologist. For the purposes of this commentary, that means two things. First, that I have spent a *lot* of time underwater. Second, although I am a biologist and understand quite a bit about animal physiology, I am not an expert in decompression physiology. Keep these two things in mind when you read what I have to say.

Back before the concept of "technical diving" existed, I used to do more dives to depths of 54-66 m (180-220 ft) than I care to remember. Because of the tremendous sample size of dives, I eventually began to notice a few patterns. Quite frequently after these dives, I would feel some level of fatigue or malaise. It was clear that these post-dive symptoms had more to do with inert-gas loading than with physical exertion or thermal exposure, because the symptoms would generally be much more severe after spending less than an hour in the water for a 60 m (200 ft) dive than they would after spending 4 to 6 hours at much shallower depths.

The interesting thing was that these symptoms were not terribly consistent. Sometimes I hardly felt any symptoms at all. At other times I would be so sleepy after a dive that I would find it difficult to stay awake on the drive home. I tried to correlate the severity of symptoms with a wide variety of factors, such as the magnitude of the exposure, the amount of extra time I spent on the 3 m (10 ft) decompression stop, the strength of the current, the clarity of the water, water temperature, how much sleep I had the night before, level of dehydration, etc; but none of these obvious factors seemed to have anything to do with it. Finally I figured out what it was. On dives when I collected fish, I had hardly any post-dive fatigue. On dives when I did not catch anything, the symptoms would tend to be quite severe. I was actually quite amazed by how consistent this correlation was.

The problem, though, was that it did not make any sense. Why would these symptoms be less when catching fish? In fact, I would expect *more* severe symptoms after fish-collecting dives because my level of exertion, while on the bottom, during those dives tended to be greater (chasing fish is not always easy). There was one other difference, though. Most fishes have a gas-filled internal organ called a swim bladder which is basically a fish buoyancy compensator. If a fish is brought straight to the surface from 60 m (200 ft), its swim bladder would expand to about seven times its original size and crush the other organs. Because I generally wanted to keep the fishes I collected alive, I would need to stop at some point during the ascent and temporarily insert a hypodermic needle into their swim bladders, venting off the excess gas. Typically, the depth at which I needed to do this was much deeper than my first required decompression stop. For example, on an average 60 m (200 ft) dive, my first decompression stop would usually be somewhere in the neighbourhood of 15 m (50 ft), but the depth I needed to stop for the fish would be around 37.5 m (125 ft). So, whenever I collected fish, my ascent profile would include an extra 2-3 minute stop much deeper than my first "required" decompression stop. Unfortunately, this did not make any sense either. When you think only in terms of dissolved gas tensions in blood and tissues (as virtually all decompression algorithms in use today do), you would expect more decompression problems with the included deep stops because more time is spent at a greater depth.

As someone who tends to have more faith in what *actually* happens in the real world than what *should* happen according to the theoretical world, I decided to start including the deep stops on all of my decompression dives, whether or not I collected fish. Guess what? My symptoms of fatigue virtually disappeared altogether! It was nothing short of amazing! I actually started getting some work done during the afternoons and evenings of days when I did a morning deep dive. I started telling people about my amazing discovery, but was invariably met with scepticism, and sometimes stern lectures from "experts" about how this must be wrong. "Obviously," they would tell me, "you should get out of deep water as quickly as possible to minimise additional gas loading." Not being a person who enjoys confrontation, I kept quiet about my practise of including these "deep decompression stops". As the years passed, I became more and more convinced of the value of these deep stops for reducing the probability of DCI. In all cases where I had some sort of post-dive symptoms, ranging from fatigue to shoulder pain to quadriplegia in one case, it was on a dive where I omitted the deep decompression stops.

As a scientist by profession, I feel a need to understand mechanisms underlying observed phenomena. Consequently, I was always bothered by the apparent paradox of my decompression profiles. Then I saw a presentation by Dr David Yount at the 1989 meeting of the American Academy of Underwater Sciences (AAUS). For those of you who do not know who he is, Dr Yount is a professor of physics at the University of Hawaii, and one of the creators of the "Varying-Permeability Model" (VPM) of decompression calculation.[1] This model takes into account the presence of "micronuclei" (gas-phase bubbles in blood and tissues) and factors that cause these bubbles to grow or shrink during decompression. The upshot is that the VPM calls for initial decompression stops that are much deeper than those suggested by neo-Haldanian ("compartment-based") decompression models. It finally started to make sense to me.

Since you already know I am not an expert in diving physiology, let me explain what I believe is going on in terms that educated divers should be able to understand. First, most readers should be aware that intravascular bubbles are routinely detected after the majority of dives, even "no-decompression" dives. The bubbles are there. They just do not always lead to DCI symptoms. Now, most deep decompression dives conducted by "technical" divers (as opposed to commercial or military divers) are very much sub-saturation dives. In other words, they have relatively short bottom-times (I would consider 2 hours at 90 m (300 ft) a "short" bottom time in this context). Depending on the depth and duration of the dive, and the mixtures used, there is usually a relatively long ascent "stretch" (or "pull") between the bottom and the first decompression stop as calculated by any theoretical compartment-based model. The shorter the bottom time, the greater this ascent stretch is. Conventional mentality holds that you should "get the hell out of deep water" as quickly as possible to minimise additional gas loading. Many people even believe that you should use faster ascent rates during the deeper portions of the ascent. The point is, divers are routinely making ascents with relatively dramatic drops in ambient pressure in relatively short periods of time, just so they can "get the hell out of deep water".

This, I believe, is where the problem is. Maybe it has to do with the time required for blood to pass all the way through a typical diver's circulatory system. Perhaps it has to do with tiny bubbles being formed as blood passes through valves in the heart, and growing large due to gas diffusion from the surrounding blood. Whatever the physiological basis, I believe that bubbles are being formed and/or are encouraged to grow in size during the initial non-stop ascent from depth. I have learned a lot about bubble physics over the last year, more than I want to relate here. I will leave that for someone who really understands the subject. For now, suffice it to say that whether or not a bubble will shrink or grow depends on many complex factors, including the size of the bubble at any given moment. Smaller bubbles are more apt to shrink during decompression; larger bubbles are more apt to grow and possibly lead to DCI. Thus, to minimise the probability of DCI, it is important to keep the size of the bubbles small. Relatively rapid ascents from deep water to the first required decompression stop *do not* help to keep bubbles small! By slowing the initial ascent to the first decompression stop, (e.g., by the inclusion of one or more deep decompression stops), perhaps the bubbles are kept small enough that they continue to shrink during the remainder of the decompression stops.

If there is any truth to this, I suspect that the enormous variability in incidence of DCI has more to do with the pattern of ascent from the bottom to the first decompression stop, than it has to do with the remainder of the decompression profile. DCI is an extraordinarily complex phenomenon, more complex than even the most advanced diving physiologists have been able to elucidate. The unfortunate thing is that we will likely never understand it entirely, largely because our bodies are incredibly chaotic environments, and that level of chaos will hinder any attempts to make predictions about how to avoid DCI. But I think that we, as sub-saturation decompression divers, can significantly reduce the probability of getting bent if we alter the way we make our initial ascent from depth.

Some of you may now be thinking "But he said he's not an expert in diving physiology. Why should I believe him?" If you are thinking this, then good, that is exactly what I want you to think because you should not trust just me. So before you make your mind up read Bruce Weinke's article in issue 3 of *DeepTech*.[2] It covers some pretty sophisticated stuff, but you should keep re-reading it until you *do* understand it. Unfortunately you can no longer call *aquaCorps*, which has gone out of business. So you cannot order audio tape number 9 ("Bubble Decompression Strategies") from the tek.95 conference in order to hear Eric Maiken explain a few things about gas physics that you probably did not know before. Nor the audio tape from the "Understanding Trimix Tables" session at the recent tek.96 conference with Andre Galerne (arguably the "father of trimix") talking about how the incidence of DCI was reduced dramatically when they included an extra deep decompression stop over and above what was required by the tables. On the same tape Jean-Pierre Imbert of COMEX (the French commercial diving operation which conducts some of the world's deepest dives) talks about a whole new way of looking at decompression profiles which includes initial stops that are much deeper than most tables call for. However, you can get your hands on a copy of issue 6 of *DeepTech* and read Eric Maiken's article.[3] Why not find out what George Irvine meant when he said he includes "three or four short deep stops into the plan prior to using the first stop recommended by each of the [decompression] programs" in issue 4 of *DeepTech* ?[4] If that is not enough, then check out Dr. Peter Bennett's editorial where he talks about basically the same thing in the context of recreational diving.[5] If you really want to read an eye-opening article, see if you can find the report on the habits of diving fishermen in the Torres Strait by LeMessurier and Hills.[6] The list goes on and on. The point is, I am not the only one advocating deep decompression stops.

Are you still sceptical? Let me ask you this. Do you believe that so-called “safety stops” after so-called “no-decompression” dives are useful in reducing probability of DCI? If not, then you should take a look at the statistics compiled by Diver’s Alert Network. If so, then you are already doing “deep stops” on your “no-decompression” dives. If it makes you feel better, then call the extra deep decompression stops “deep safety stops” which you do before you ascend to your first “required” decompression stop. Think about it this way. Your first “required” decompression stop is functionally equivalent to the surface on a dive that is *taken to the absolute maximum limit* of the “no-decompression” bottom time. Would you not think that “safety stops” on “no-decompression” dives would be *most* important after a dive made all the way to the “no-decompression” limit?

Some of you may be thinking, “I already make safety stops on my decompression dives. I always stop 3 or 6 m (10 or 20 ft) deeper than my first required stop.” While this is a step in the right direction, it is *not* what I am talking about here. “Why not?”, you ask, “I do my safety stops on no-decompression dives at 6 m (20 ft). Why should I not do my deep safety stops 6 m (20 ft) below my first required ceiling?” I will tell you why not, because the deep safety stops seem to have to do with preventing bubble growth and bubble growth is in part a function of a change in ambient pressure, *not* a function of linear depth. Suppose that, after a dive to 22.5 m (75 ft), you make a safety stop at 6 m (20 ft). Well, the ambient pressure at sea level is 1 bar (ATA). The ambient pressure at 22.5 m (75 ft) is about 3.3 bar (ATA). The ambient pressure at your 6 m (20 ft) safety stop is 1.6 bar (ATA). This represents roughly one half the total ambient pressure of the bottom. Now, suppose you are on a dive to 60 m (200 ft) where the ambient pressure is about 7 bar and your first required decompression stop is 10 m (33 ft or 2 bar). However half the ambient pressure of the bottom would be 3.5 bar or 25 m (about 83 ft). Thus, on this dive you would want to make your deep safety stop at about 25 m (83 ft) to have roughly the same relative effect on ambient pressure.

But of course, the physics and physiology are much more complex than this. It may be that half of the ambient pressure of the bottom is not the ideal depth for a safety-stop. In fact, I can tell you with near certainty that it is not. From what I understand of bubble-based decompression models, initial decompression stops should be a function of absolute ambient pressure changes, rather than proportional ambient pressure changes, and thus should be even deeper than half of the bottom ambient pressure for most of our decompression dives. Unfortunately, I seriously doubt that decompression computers will begin incorporating bubble-based decompression algorithms, at least not in their complete form. Until then, we decompression divers need a simpler method, a rule of thumb to follow that does not require the processing power of an electronic computer.

Perhaps the ideal method would be simply to slow down the ascent rate during the deep portion of the ascent. Unfortunately, this is rather difficult to do, especially in open water. Instead, I think you should include one or more discrete, short-duration stops to break up those long ascents. Whether or not it is physiologically correct, you should think of them as pit-stops to allow your body to “catch up” with the changing ambient pressure.

Here is my method for incorporating deep safety stops:

1 Calculate a decompression profile for the dive you wish to do, using whatever software you normally use.
2 Take the distance between the bottom portion of the dive (at the time you begin your ascent) and the first “required” decompression stop, and find the midpoint. This depth will be your first deep safety stop, and the stop should be about 2-3 minutes in duration.
3 Re-calculate the decompression profile by including the deep safety stop in the profile (most software will allow for multi-level profile calculations).
4 If the distance between your first deep safety stop and your first “required” stop is greater than 9 m (30 ft), then add a second deep safety stop at the midpoint between the first deep safety stop and the first required stop.
5 Repeat as necessary until there is less than 9 m (30 ft) between your last deep safety stop and the first required safety stop.

For example, suppose you want to do a trimix dive to 90 m (300 ft), and your desktop software says that your first “required” decompression stop is 30 m (100 ft). You should recalculate the profile by adding short (2 minute) stops at 60 m (200 ft), 45 m (150 ft), and 37.5 m (125 ft). Of course, since your computer software assumes that you are still on-gassing during these stops, the rest of the calculated decompression time will be slightly longer than it would have been if you did not include the stops. However, in my experience and apparently in the experience of many others, the reduction in probability of DCI will far outweigh the costs of doing the extra hang time. In fact, I would be willing to wager that the advantages of deep safety stops are so large that you could actually reduce the total decompression time (by doing shorter shallow stops) and *still* have a lower probability of getting bent, but until someone can provide more evidence to support that contention, you should definitely play it safe and do the extra decompression time.

One final point. As anyone who reads my posts on the internet diving forums already knows, I am a *strong* advocate of personal responsibility in diving. If you choose to follow my suggestions and include deep safety stops on your decompression dives, then that is fine. If you decide to continue following your computer-generated decompression profiles, that is fine too. But whatever you do, ***you are completely and entirely responsible for***

whatever happens to you underwater! You are a terrestrial mammal. You have no business going underwater in the first place. If you cannot accept the responsibility, then stay out of the water. If you get bent after a dive on which you have included deep safety stops by my suggested method, then it was your own fault for being stupid enough to listen to decompression advice from an ichthyologist.

Acknowledgment

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WHEN THINGS GO WRONG

Brian Cumming

Key Words

Accidents, deaths, decompression illness, equipment, incidents, safety, trauma.

Most of the 315 UK sports diving incidents that occurred in the 12 months to the end of September 1996 could have involved any one of us. Sure, there were a number of really stupid ones that I hope most people would have avoided, but it is all too easy to adopt a self-righteous attitude towards the mishaps of others. Who, if we are honest, can claim an error-free diving career?

The 1996 incidents represent a 10 per cent reduction on the number recorded in the previous year, which itself was 9 per cent down on 1994. We cannot be sure that this indicates increasing safety, but it is clearly a trend in the right direction.

Data for the BSAC's annual report comes from its own incident reporting scheme, the Coastguard, Royal National Lifeboat Institution, British Hyperbaric Association (BHA), through the Institute of Naval Medicine (INM), newspapers and other independent sources.

We also receive information on overseas incidents but only record and publish those relating to BSAC (British Sub-Aqua Club) members and do not count them in the statistical analyses.

TABLE 1

INCIDENTS BY MAJOR CATEGORY

Boat or surface*	98
Decompression illness*	77
Injury	30
Overseas	29
Ascents	22
Technique	22
Equipment	19
Deaths*	16
Miscellaneous	2
Total	315

These figures were obtained from a coloured bar graph, which did not translate well into black and white, by measurement of the bar heights and the numbers scale height.
* These figures were obtained from the text.