First Aid Oxygen Update

In a previous article, we discussed basic diving gas physics. In short, we concluded that the more oxygen you breathe, the more the nitrogen (presumed the key player in the development of decompression sickness, or DCS) is washed out of the tissues.

Remember that the lung is primarily a large surface area: When spread out, it's about the size of a tennis court. Only a single thin layer of cells separates blood from the air we breathe, allowing for the all-important gas exchange.

When you're safely decompressing, nitrogen travels from the body's tissues through the bloodstream back to the heart and into the lungs; it crosses the thin lung cells into the lung's air sacs and is exhaled without your even realizing it. Some nitrogen molecules coalesce to become bubbles in the body if there are enough molecules around. These bubbles are frequently detected (using ultrasound technology) in the bloodstream. We routinely see bubbles at Duke during research studies; they are present even after some rather shallow dives.

Dr. R.D. Eckenhoff and colleagues at the University of Pennsylvania reported in 1990 that you could expect to detect venous bubbles in 56 percent of divers who had spent 48 hours at the shallow depth of 16 fsw (5 msw) (1). However, this saturation profile (48 hours at 16 feet/5 meters) is far longer than what the average recreational diver would experience. In addition, short, shallow dives would be far less likely to lead to measurable bubbles than a 48-hour exposure.

This was a significant discovery, however, because prior to that, few dive medicine specialists believed that bubbles were so prevalent. With rare exception, all of these bubbles are simply filtered by the lungs before they have the chance to cross into the arterial circulation, where they could do damage by obstructing blood flow.

Nitrogen bubbles can be minimized by decompressing with 100 percent oxygen; this lessens the chance of rogue nitrogen bubbles forming in appreciable numbers. If pure oxygen bubbles should make their way into the arterial circulation, these are considered less troublesome than nitrogen bubbles. That is because oxygen is a metabolic gas, i.e., a fuel, and will be consumed, unlike the inert nitrogen bubble. Any reasonably small oxygen bubble, even those that go to the brain, will be consumed eventually.

This is one of few times we can praise the brain's insatiable appetite for oxygen. (It consumes more oxygen per unit weight than any organ, and the lung consumes very little). One safety note: While underwater, to minimize the risk of central nervous system oxygen toxicity (usually seen as a seizure), never breathe 100 percent oxygen deeper than about 20 fsw (6 msw). As the risk of oxygen toxicity is smaller when the diver is at rest in a dry chamber, 100 percent oxygen is used as deep as 60 fsw (18 msw).

The Findings

Switching gears, I would like to summarize our initial findings while inters persing a bit of commentary and explanation.

We looked at 2,231 cases of DCS in the DAN diving injury database (from 1998-2003) and found that the median time from surfacing to DCS symptom onset was 2.2 hours for all DCS types combined. "Median" refers to the middle number between highest and lowest numbers. It is generally believed that almost all (95 percent) of DCS symptoms occur within the first six hours of surfacing, so 2.2 hours is not unreasonable.

When symptoms of DCS were suspected, 47 percent of the injured divers were found to have used FAO_2. I think the diving community still has a lot of room for improvement here, and I suspect that the number is higher now, given better diver education.

The type of DCS that tended to be treated with FAO_2 was interesting as well. Those divers with rather dramatic symptoms, such as those who presented with cardiopulmonary complaints (i.e., the chokes) or serious neurological complaints (i.e., paralysis) were most likely to be given FAO_2.

One interesting finding came from those divers who had skin bends, in and of itself not a lifethreatening form of DCS: Those divers were administered FAO_2 more rapidly than all other types. Their median time to FAO_2 was 18 minutes. This rapid initiation of FAO_2 may be because skin bends are easily seen by all those around and are frequently dramatic-appearing rashes. We were surprised to learn that the median wait for divers with serious neurological symptoms like leg weak ness, paralysis or depressed level of consciousness was 54 minutes from symptom onset to FAO_2.

This point is worth repeating: injured divers with serious neurological symptoms tended to wait some 54 minutes for FAO_2. Most dive medicine specialists would agree that a paralyzed diver should begin receiving oxygen much sooner than 54 minutes after symptom onset. If you had simple pain in a joint, the wait was a little more than three hours after onset of symptoms. Numbness and tingling? Almost six hours. If you get bent, we would hope you would be started on breathing 100 percent oxygen more quickly.

Out of the 2,231 cases, we had very little information about outcomes on those who received FAO_2 before they were put in a hyperbaric chamber. In fact, we had only 330 cases in which we knew how the diver felt after being given FAO_2 but before hyperbaric treatment. Of those 330 divers, 65 percent (205 divers) reported either complete relief of symptoms or improvement with FAO_2 alone.

This is an inspiring finding but not strong enough to preclude the need for further hyperbaric treatment, which is still the definitive therapy. If you add a hyperbaric treatment after the FAO_2, the group with complete relief jumps to 67 percent compared with those who didn't have FAO_2 (58 percent with complete relief).

In other words, when you receive FAO_2 before the hyperbaric treatment, the chance that you will have complete relief after your first hyperbaric treatment is greater. This finding was statistically significant.

What about the chance of FAO_2 decreasing the total number of hyperbaric treatments required to fully treat an injured diver? Well, we found that those who had FAO_2 less than four hours from DCS symptom onset were less likely to require more than one hyperbaric treatment.

In other words, if you receive FAO_2 quickly, the chances are greater you'll need only one hyperbaric treatment. At the very least, oxygen should be available on all diving vessels. There should be enough oxygen onboard to treat one or two divers for the entire time it takes to get to the hospital.

Getting the most out of your oxygen

A high-efficiency, low-flow rebreather such as the Remote Emergency Medical Oxygen unit ($REMO_2$™) – (see Figure 1) or similar devices are well worth considering, especially if you're diving in more remote locales, i.e., far from medical facilities. These devices can very efficiently deliver more than 90 percent inspired oxygen with a miniscule 1 L/min oxygen flow rate average.

It can do this by recycling the unused oxygen in your exhaled breath. The REMO$_2$™ uses an oronasal resuscitation mask that makes an effective seal against the face. Few units are this efficient. In the case of a stable injured diver who does not need helicopter evacuation, this will allow much more time for the boat to make the trip back to shore, before the oxygen supply is depleted.

As a comparison, the plastic oxygen masks (without reservoir bag) seen in hospitals require 13-15 liters per minute (L/min) to attain 50 percent inspired (breathed) oxygen. Nasal prongs are much less effective, raising inspired oxygen only a few percent higher than air. We found that an alarming 7 percent of injured divers given FAO$_2$ still used nasal prongs. Most providers used the commonly available and reasonably efficient nonrebreather mask (37 percent). Found in emergency rooms, these are the fairly efficient, flexible plastic masks with the plastic reservoir bag attached beneath.

So, how much oxygen should you bring with you on your dive trip? Here's a small chart (Table 1) comparing inefficient modes of FAO$_2$ delivery (15 L/min) to the efficient REMO$_2$™ unit (1.3 L/min average)*. The difference is remarkable. I have included, via simple math, an explanation that you can adapt when using different size cylinders. Always remember to allow for delays, and bring a little more than you think you may need for the boat trip back.

In conclusion

We still need to learn more about those divers who use FAO$_2$ alone and without hyperbaric treatment as well as those who use FAO$_2$ alone without seeking formal medical attention.

Table 1: Different Methods of Oxygen Delivery

Desired O$_2$ Duration (hrs)	High Flow Oxygen (15L/ min) i.e., inefficient O$_2$ use. Total Liters of O$_2$ Used	Number of umbo-D cylinders needed	Low Flow (1.3 L/min) i.e., efficient O$_2$ use. Total Liters of O$_2$ Used*	Number of Jumbo-D cylinders needed
1	0,9	1 ½	78	< ¼
2	1,8	2 ¾	156	¼
3	2,7	4 ¼	234	< ½
4	3,6	5 ¾	312	½
5	4,5	7	390	< ¾
6	5,4	8 ½	468	¾
7	6,3	9 ¾	546	< 1
8	7,2	11 ¼	624	1
9	8,1	12 ¾	702	< 1 ¼
10	9,0	14	780	1 ¼

This information is based on the REMO$_2$™ system, however, this system is no longer in use. Medical oxygen rebreathers similar to the outdated REMO$_2$™, such as the Wenoll system, are currently utilized in Europe and produce similar results.

About the Author

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