Carbon Dioxide – the Dreaded Enemy (part 1)

This is the first part of a three-part series on carbon dioxide, a common contributor to diving emergencies. Parts two and three will be published in future issues of Alert Diver.

A close call

Please allow me to begin with a personal story: Back in 2016, I joined a cave dive in Cenote Regina, near Tulum in Quintana Roo, Mexico. Our objective was to visit the salt water section, which runs at depths of around 30 meters, with a maximum of 34 meters for that particular dive. We went in with four AL80 cylinders (doubles and two stages) of EAN32, plus an AL40 of oxygen for deco, which we staged near the entrance at a depth of 6 meters. The planned dive duration was 200 to 210 minutes.

I also went in on no more than three hours of sleep the night before due to work commitments – not the best idea in hindsight. However, I didn't have the benefit of hindsight when I made the decision, and I very much wanted to go, so there's that.

Cenote Regina is stunningly beautiful, and everything went smoothly at first. We hit turn pressure and began our return toward the entrance about 90 minutes into a highly enjoyable dive. Ahead of us lay a swim back of roughly equal duration, followed by twenty minutes to so of decompression in shallow water.

Maybe ten minutes later, at around minute 100, I began to experience a very peculiar sensation: My diaphragm started to flutter, and my breathing gradually turned into what I can only describe as uncontrollable sobbing, albeit without any of the emotional content that generally comes attached to this kind of physiological manifestation. I tried to focus and bring my muscles back under control, but the sobbing only became more pronounced. I realized that I probably wasn't breathing very efficiently and blowing more bubbles than usual.

Photo by Joram Mennes

It didn’t take very long for my state of mind to take a hit as well: Anxiety began to creep in, along with the feeling that I couldn’t draw enough air from my second stage. I switched to the backup just in case, with zero effect.

I signaled the team that I was having a problem, and we stopped. I began to feel the urge to bolt for the surface, an utterly unhelpful demand from the nether regions of my central nervous system, given that we were almost two hours away from the exit with thirty meters of rock and soil above us.

I spent the next several minutes – not sure how long exactly, but it felt like an eternity – debating a voice in my head trying to convince me that it would be okay to give up right there. People would understand. Beating that voice back into the hole it had crawled out from took a dedicated effort of will, and I will readily admit that the outcome wasn’t a foregone conclusion.

Eventually the sobs subsided, and we continued on our way back at a slow pace. The delay and my elevated rate of breathing had taken a bite out of our reserves. Although we were nowhere near low on gas, finding the first stage bottle with another 110 bar of nitrox in it came as a relief.

We ended the dive with a delay of half an hour as a result of the break I had to take and the resulting increased deco obligation. But we were out. I went back to cave diving the next day, with a resolution to sleep more and fry slightly smaller fish, at least in the near future.

In the post-dive discussion, we determined that the main cause of my problem had probably been carbon dioxide buildup in my bloodstream, with fatigue from lack of sleep as a contributing factor. Which takes us to the subject of this article.

Photo by Joram Mennes

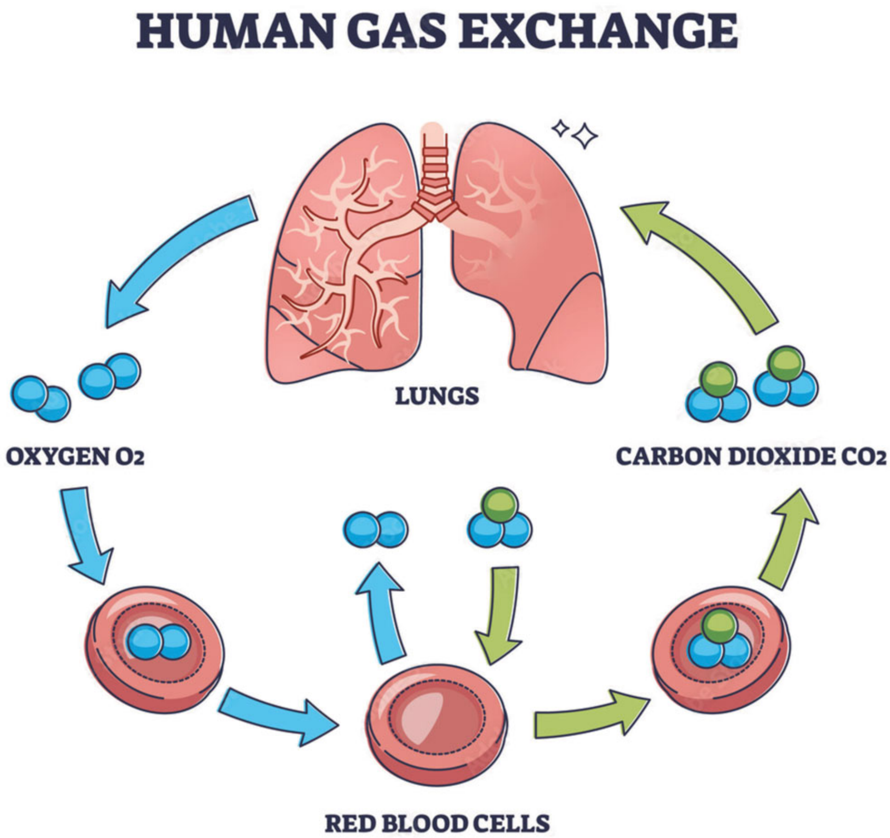
The metabolism of carbon dioxide, in a (very small) nutshell

Carbon dioxide is a waste product of our cell metabolism. We inhale gas that contains oxygen. Our lungs absorb a portion of that oxygen into the bloodstream, where it is picked up by the red blood cells (*hemoglobin*). The oxygen-rich blood passes through the left side of the heart, from where it is pumped first to the brain and central nervous system, then on to the remainder of our body.

In the various body parts, a set of biochemical reactions take place in which the oxygen is combined with carbon (taken in through food) to form carbon dioxide. These reactions generate the energy that keeps us going.

The oxygen-depleted blood, now carrying carbon dioxide in a variety of forms, travels back toward the right side of the heart, which pumps it to the lungs, where carbon dioxide is removed and eventually exhaled.

Note: The actual mechanics are significantly more complex. CO_2 is not purely a waste product. It plays an important role in regulating blood acidity, and less than 10% of the total CO_2 contained in the blood is removed on each pass through the lungs. Some details can be found [here](#).



Getting a measure of the villain

There are a number of measurable physiological quantities which describe this process. The capacity of our lungs to absorb oxygen is referred to as *VO_2 max*. VO_2 max describes the maximum volume of oxygen our lungs are able to provide to our body for energy generation, per unit of time and relative to body weight. Endurance athletes are familiar with it as a measure of cardiovascular performance.

A second important quantity is called *respiratory exchange ratio*, usually abbreviated as *RER*. RER describes the ratio of carbon dioxide elimination to oxygen uptake. A normal RER for a human at rest is 0.8. That's right: At rest, we exhale only four molecules of CO_2 for every five molecules of O_2 we consume. The balance of the oxygen remains in the body. Under exertion, RER can go up to as high as 1.2 and above. This means that our metabolism is tapping into oxygen reserves that were stored in our muscles (chemically bonded to *myoglobin*) during rest. A RER of 1.0 is referred to as the *anaerobic threshold*, another term familiar to athletes.

Under exertion, our body has an increased demand for oxygen and produces more carbon dioxide. When the amount of CO_2 produced exceeds the capacity of our respiratory metabolism to remove it from the bloodstream and exhale, then CO_2 begins to accumulate. As any freediver knows, the feeling of being air-starved and the urge to breathe aren't caused by lack of oxygen – there is plenty of the stuff to go around under most circumstances, and lack of it simply makes you pass out – but by excess CO_2, a condition known as *hypercapnia.*

This concludes the first part of our little series. In part two, we will take a closer look at the physiology of carbon dioxide in the human body, how it is affected by diving, and what makes hypercapnia so dangerous . Part three will focus on countermeasures – skills and procedures to keep our CO_2 load in check. Stay safe *and stay tuned!*

The underwater photos found in this article feature the stunning Cenote Regina. They were taken by Joram Mennes, with model diver Stratis Kas. Thanks to both for taking these magnificent shots, expressly for this Alert Diver content.

About the author

Tim Blömeke teaches technical and recreational diving in Taiwan and the Philippines. He is also a freelance writer and translator, as well as a member of the editorial team of Alert Diver. He dives a Fathom CCR. For questions, comments, and inquiries, you can contact him via his blog page or on Instagram.