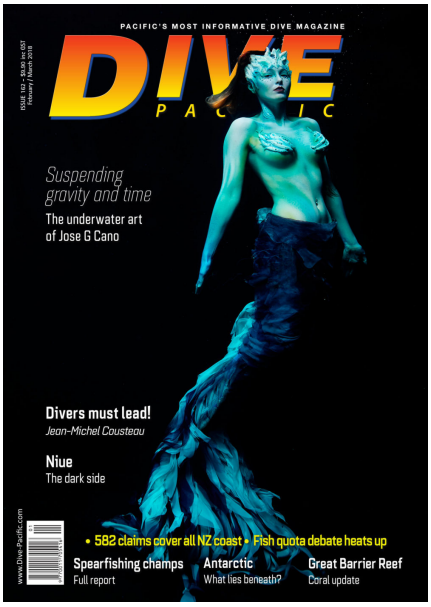

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Advanced Knowledge Series: The Five-minute Prebreathe

Posted on 11/08/2016 by Sophie Fraser in Dive Medicine, Diving in New Zealand, Technical Diving/Re-breathers

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Introduction and recap

This is the third in a series of articles appearing in Dive New Zealand/Pacific with the aim of enhancing knowledge of selected practically important issues in diving physiology and medicine. In the first article we discussed how CO_2 is produced in the tissues during the utilisation of oxygen. CO_2 is eliminated from the body by breathing, and the more we breathe the more CO_2 is eliminated. This process of elimination is usually precisely controlled by the brain to keep CO_2 in the body at a stable level. If CO_2 levels rise, the brain will 'drive' more breathing to bring CO_2 back to normal and vice versa. This is a completely automatic function which takes place without us thinking about it.

This normal process of CO_2 control can be disturbed in diving because of an increase in the work required to breathe. The work of breathing increases because we are respiring a denser gas through a regulator or rebreather. In some people more than others, when the work of breathing rises, the brain seems less sensitive to rising levels of CO_2 and will avoid

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driving the extra breathing work required to keep CO_2 levels normal. Thus, when underwater, divers are prone to having CO_2 levels rise, particularly when exercising and when the work of breathing is high. We refer to this as 'CO_2 retention'.

In the previous articles we discussed the reasons why increasing CO_2 levels are dangerous. In particular, high CO_2 can produce symptoms such as headache, shortness of breath and anxiety. At very high levels these symptoms might lead to panic and drowning. In addition, high CO_2 levels increase narcosis and are a significant risk factor for oxygen toxicity which is a concern for technical divers. These divers are taught to monitor their oxygen exposure using tables that are in some ways analogous to dive tables. The oxygen exposure is a function of the PO_2 breathed, and the duration of exposure to that pressure. Thus, for a given PO_2 the table will tell the diver the recommended maximum time for a 'safe' exposure. As you might imagine, as the respired PO_2 increases, the duration of 'safe' exposure is reduced and vice versa.

The hazards of CO_2 inhalation

Another cause of increased CO_2 levels during diving is inhalation of CO_2 during breathing. If a diver is inhaling CO_2 then breathing becomes much less efficient at removing CO2 from the lungs and CO_2 levels in the body can therefore increase even if the diver breathes heavily. The more CO_2 is inhaled, the worse this problem is likely to be.

CO_2 inhalation is a specific hazard of rebreather diving because these devices recycle the exhaled gas which is 'rebreathed'. The CO_2 must obviously be removed from the exhaled gas and this is achieved by passing it through a CO_2 'scrubber' canister, which contains a granular chemical preparation called 'soda lime'. Soda lime reacts with CO_2 to produce calcium carbonate and water. It is a non-reversible consuming reaction and a given volume of soda lime can only absorb a finite amount of CO_2. It follows that divers must carefully track the dive-time they have accumulated on their current canister of soda lime and replace it in a timely manner (typically after 3–5 hours of use). Failure to do this may result

in exhaustion of scrubbing capacity and therefore in exhaled CO_2 'breaking through' the scrubber canister and being rebreathed. Rebreathing can also occur if the diver packs or installs their scrubber canister incorrectly, or forgets to install it at all. (This has actually happened!)

Prebreathing a rebreather

Partly for the above reasons, rebreather divers are taught to 'prebreathe' their units prior to entering the water. There are multiple good reasons for doing a prebreathe. One frequently cited reason is that it is a means of evaluating whether the CO_2 scrubber is working properly. The idea is that the diver will develop symptoms of CO_2 toxicity (shortness of breath or headache) during a 5-minute prebreathe if the scrubber is not working correctly and CO_2 is breaking through. This will alert the diver that there is a problem and they should check the rebreather.

The prebreathe study

We were unsure whether this was a valid assumption and so we evaluated it in a recent study. Twenty divers prebreathed on a rebreather in each of the following conditions: normally functioning CO_2 scrubber, absent CO_2 scrubber, and partly failing CO_2 scrubber. The latter condition was established by committing a well-known assembly error particular to the rebreather being used in the experiments. The subjects were blinded to the scrubber condition but knew they might be breathing on a rebreather with a normal or faulty scrubber. They were told to treat the event like a normal prebreathe and to terminate the procedure if they developed symptoms they thought might be CO_2-related. We measured CO_2 levels in the inspired and exhaled breath (the latter being a good estimate of body CO_2 levels).

As we expected none of the 20 subjects breathing on a rebreather with a normal scrubber terminated the prebreathe. It was in the experiments with the absent or faulty scrubber that things got very interesting. In the absent-scrubber condition where all exhaled CO_2 was re-inhaled the

subjects' inhaled and body-CO_2 levels rose very quickly. Fifteen of the 20 subjects terminated the prebreathe, but 5/20 (25%) completed the 5 minutes and reported feeling nothing wrong. In the partial-failure condition the inhaled CO_2 levels rose significantly, to levels that would be dangerous in the water, but not as high as in the absent-scrubber condition. Only 2/20 subjects (10%) terminated the prebreathe when breathing on a rebreather in the partial-failure condition. Put another way, 90% of subjects would have been happy to dive a rebreather with a significant fault in CO_2 removal capability.

These results cause us to conclude that the 5-minute prebreathe is not a reliable test of CO_2 scrubber performance in a diving rebreather. Unfortunately, until CO_2 detecting devices become widespread in rebreathers, there is no reliable way for the diver to verify scrubber function. A prebreathe should still be completed to check other rebreather functions before entering the water, but a lack of obvious CO_2 toxicity symptoms during the prebreathe should not be interpreted as proving that the scrubber is working correctly.

Reference:

Deng C, Pollock NW, Gant N, Hannam JA, Dooley A, Mesley P, Mitchell SJ. The five minute prebreathe in evaluating carbon dioxide absorption in a closed-circuit rebreather: a randomised single-blind study. Diving Hyperbaric Med 45, 16–24, 2015.

Tagged Advanced Knowledge Series CO2 co2 scrubber Dive Medicine diving five minute prebreathe issue-154 oxygen toxicity Prebreathe Simon Mitchell study Technical Diving/Re-breathers test the prebreathe study

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