Advanced Knowledge Series: Are All Carbon Dioxide Absorbents the same?

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Introduction and recap

This is the fifth in a series of articles appearing in Dive New Zealand with the aim of enhancing knowledge of selected practically important issues in diving physiology and medicine. In the first article we discussed how carbon dioxide (CO_2) is produced in the tissues during the utilisation of oxygen. CO_2 is eliminated from the body by breathing, and in the previous articles we have considered how breathing is controlled so that when CO_2 production increases (for example during exercise), then breathing will also increase to eliminate the extra CO_2 and keep CO_2 levels in the body normal.

In subsequent previous articles we discussed several ways in which the normal control of breathing can be disturbed in diving (particularly because of higher work of breathing) and how it is not uncommon to develop higher than normal body CO_2 levels in diving. This was coupled with a discussion of why this can be 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.

Rebreathers and the possibility of rebreathing CO_2

One potential contributor to higher CO_2 levels that we have not considered previously is the inhalation of CO_2 during use of a rebreather. Normally the gas we respire (for example, the air around us) contains only a tiny and inconsequential amount of CO_2. But during use of a rebreather, because the exhaled breath is recycled, there is the possibility of re-inhaling our own expired CO_2. If CO_2 is actually inhaled, then its elimination from the body is reduced; potentially markedly so.

Rebreather divers rely on a canister of CO_2 'scrubber' material to remove the CO_2 from the exhaled breath before it is re-inhaled. This canister contains a compound material called 'soda-lime' which comes as a preparation of tiny hard granules 1–2mm in size. Through a series of chemical reactions, exhaled CO_2 is combined with calcium hydroxide to produce calcium carbonate. Because this reaction is uni-directional, the absorptive capacity of a given amount of soda-lime is finite. Most rebreathers contain enough soda-lime to provide three hours or more of efficient CO_2 absorbing function, even with moderate exercise. However, if the diver fails to replace the soda-lime in a timely manner, or if they work hard and produce a lot of CO_2 toward the end of a long dive when the soda-lime absorptive capacity is declining, then there is a real possibility of CO_2 breaking through the scrubber, being re-inhaled, and leading to the development of high body CO_2 levels.

Figure 1 – Benchtop rebreather testing setup with an Inspiration Evo+ rebreather incorporated in a test circuit in which ventilation and CO_2 introduction simulated moderate exercise.

Different soda-lime preparations

One issue that has caused a degree of confusion and debate in the rebreather diver community is the difference between various soda-lime preparations. In general, preparations with a smaller granule size will, when packed into a scrubber canister, have a larger total surface area and be more efficient at CO_2 absorption than preparations with a larger granule size. Smaller granules are therefore appropriate for applications like diving rebreathers where the user may be exercising, breathing quickly, and producing a lot of CO_2. In this setting the scrubber canister must quickly remove large amounts of CO_2 from gas that is passing quickly through the soda-lime. The trade-off is that smaller granules result in a higher work of breathing.

Soda-lime is also used in anaesthetic circuits in hospitals. In that setting soda-lime with larger granules it typically used because keeping the work of breathing low is important for sick frail patients, and the CO_2 production by anaesthetised patients is almost always small. Because these medical soda-lime preparations are so widely used throughout the world they are often more readily available and cheaper than preparations made specifically for diving. This has inevitably resulted in divers using medical soda-lime in rebreathers. There has been debate about the advisability of this process on internet forums, and occasionally there have been claims that medical preparations are just as good as the diving ones.

A relevant experiment

We recently conducted a series of experiments with the aim of developing a sense of how much difference in CO_2 scrubbing performance there might be between a soda-lime preparation designed specifically for diving (called sofnolime 797) and a commonly used medical preparation (called spherasorb). We set up a rebreather containing either preparation in the scrubber (five experiments using each type) in a bench-top test circuit (see Figure 1) and ran it at a ventilation level and CO_2 introduction rate that simulated moderate exercise by a diver.

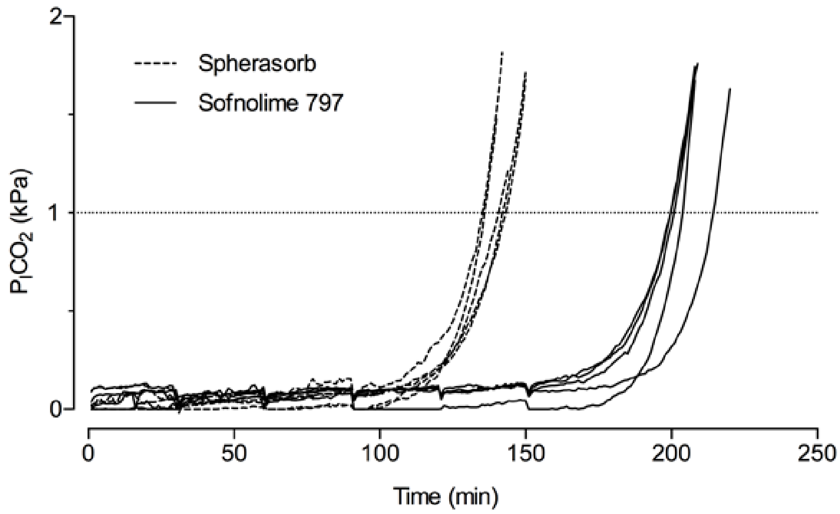

Figure 2 – Breakthrough curves for five scrubber canisters of each type showing the time taken (horizontal axis) for the canister to reach an inspired PCO_2 of 1 kilopascal (vertical axis). Reproduced with permission from Harvey et al. (See reference below.)

Each experiment continued until there was CO_2 breakthrough (that is, CO_2 passing through the scrubber) to a level that is known to be hazardous for a diver to inhale (a PCO_2 of 1 kilopascal). The results are shown in Figure 2.

There is a substantial difference between the preparations with spherasorb on average lasting 138 minutes vs sofnolime at 200 minutes. On this basis we would, in general, recommend that divers should avoid using medical soda-lime preparations in rebreathers. To avoid any ambiguity, I should point out that spherasorb is a perfectly good product for its intended use in medical anaesthetic circuits. Indeed, we use it at Auckland City Hospital for all our anaesthetic work. However, our finding does make it clear that there are differences in performance between soda-lime preparations, and that if substituting one for another a diver cannot simply assume that performance will be equivalent.

Reference:

Harvey D, Pollock NW, Gant N, Hart J, Mesley P, Mitchell SJ. Comparison of duration of two CO_2 absorbents in a diving closed-circuit rebreather system. *Diving Hyperbaric Med* 46, 92–7. 2016

The paper can be downloaded at:
http://www.dhmjournal.com/files/Harvey_TwoCO2_Absorbents

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