Evaluating a simplified purge procedure for oxygen/nitrox switch rebreathers.

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The purging method

A simplified purging method was evaluated. On surface to start the dive the new procedure was: Three breaths was inhaled from the system and exhaled outside the system. After this three breaths were breathed in the system with only the last exhalation being expelled to the surroundings. This was then repeated with three breaths in the system with the last exhaled to the surrounding.

When changing from oxygen to nitrox, after the procedure for verifying the gas shift, three breaths was expelled from the system prior to descent.

Prior to ascending from the deep phase three breathes where expelled from the system.

Transition from nitrox to oxygen, after verifying the gas shift three breaths were expelled after which the diver swam for two minutes. The diver then expelled a further three breaths.

The final ascent to surface was conducted with the oxygen turned off to avoid oxygen dosage and slow enough to let the metabolism consume the oxygen in order not to release bubbles.

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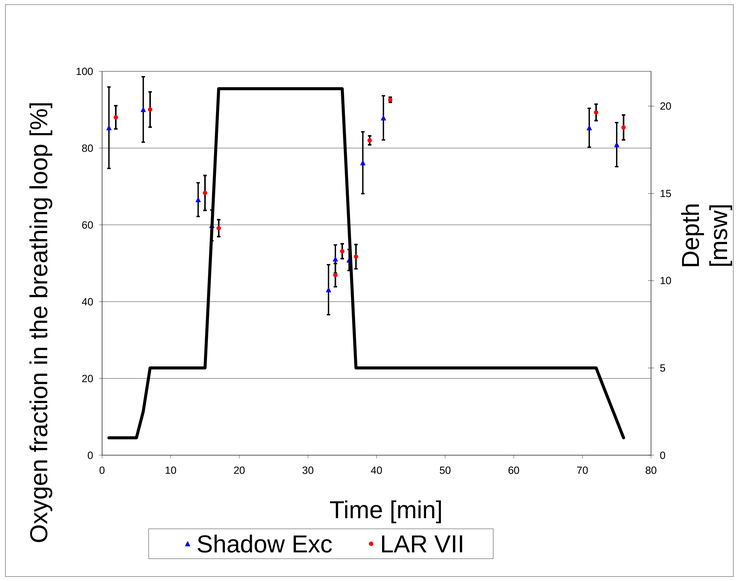
Introduction & Methods: Oxygen and nitrogen carbon dioxide levels in Shadow Excursion, Divex Ltd and LAR VII, Dräger Gmbh Oxygen/ Nitrox rebreathers were measured after new set purge procedures. Four combat divers did one chamber dive with each system working on a stationary bike with a rebreather in a water bath. After an oxygen purge the divers were pressurized to 5 msw in oxygen mode. A switch to 60%-nitrox was carried out before diving to 21 msw. After returning to 5 msw the sets were switched back to oxygen. The inhaled gas was measured in the mouth piece with a mass spectrometer (Innovision AMIS 2000) and compared with measurements from an oxygen cell (Teledyne R22 connected to a delta P VR3).

The dives were repeated in a 21 m deep submarine escape training tank and later in open sea. In both these settings the oxygen fraction was measured with the VR3.

Results: The purge at surface resulted in FO_2 of 85 ±11% for Shadow and 88 ±3% for LAR. Switching to Nitrox at 5 msw gave FO_2 67±4%, and 68±5% for Shadow and LAR, respectively, resulting in ca 60% O_2 at 21 m. Switching back to oxygen at 5 msw resulted in FO_2 after one respectively two purges of 76±8% and 88±6% for Shadow, and 82±1% and 93±1% for LAR. The pool and open water sessions gave comparable results to the chamber sessions.

Conclusion: The simplified purging procedures resulted in adequate oxygen fractions for these rebreathers.



Reported oxygen fractions and standard deviations for both breathing apparatuses;

1. After purge at surface prior to dive
2. When ariving at 5 msw
3. Post nitrox purge at 5 msw
4. When ariving at 21 msw
5. After 21 m work period pre purging
6. Post purge at 21 msw
7. When ariving at 5 msw in nitrox mode
8. First oxygen purge swiching back to oxygen
9. Second oxygen purge
10. After the 5 msw oxygen work period
11. At surface following slow ascent

End tidal carbon dioxide

The measured end tidal carbon dioxide levels during the dives were surprisingly high. At the end of the nitrox breathing at 21 msw the end tidal CO_2 was 6,6 ± 1,0 kPa for Shadow and 7,3 ± 0,9 kPa for LARVII. After the oxygen work period the measured carbon dioxide partial pressures was 6,4 ± 1,0 kPa with Shadow and 6,8 ±1,2 kPa for LAR VII. Two of the test subjects had an end tidal carbon dioxide above 7 kPa in all situations and in three of eight cases above 8 kPa .

The risk associated with hypercapnia are substantial since increased carbon dioxide can cause disturbances of the consciousness but also increase the risk of oxygen toxicity[1].

High end tidal CO_2 is often associated with increased work of breathing[2] (WOB). LAR VII has a work of breathing of about 1.7 J/l at 4.6 msw at 62.5 l/min ventilation[3]. The WOB for the Shadow excursion could not be found in the literature. The European standard for rebreathers[4] proposes a limit of 2.35 J/l at 40m depth. Warkander[5] proposes a limit decreasing with depth to counteract the increase in gas density yielding 2.41 J/L at 5 m.

The reported work of breathing was lower than the proposed limits yet the end tidal CO_2 where high. Since the WOB in this specific set up was not measured it could not be excluded that the WOB was higher than reported. But the high end tidal CO_2 could otherwise be attributed to the hyperoxic breathing mixtures[2], a learnt breathing behavior of the divers[6] or a combination of the three.

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