Unconscious Recreational Rebreather Diver and Rescue Techniques

CEDRIC VERDIER, DAVID R. LEE, Dr HOWARD SCORF

Verdier C., Lee D.R., Scorf H. – 2008 – Unconscious Rebreather Diver and Rescue Techniques – Various techniques have been designed and tried to rescue an unconscious recreational rebreather diver who passed out underwater or at the surface. A one-year study done by the authors has allowed fine-tuning some techniques to increase the chances of survival.

Keywords: rebreather, unconsciousness, blackout, rescue, hyperoxia, hypoxia, hypercapnia

Introduction

There is at the moment no guideline and no protocol for the proper rescue of an unconscious recreational rebreather diver at the surface or underwater. Protocols exist in military or commercial diving contexts but cannot be applied *in extenso* by the recreational rebreather diving community (1) (2) (3).

The authors have studied in details 32 fatalities that occurred in the past few years in the rebreather diving community (4) (5). They have also be witness of or directly involved in 3 cases of rebreather diver blackout that ended in a positive outcome. They were also instrumental in the testing phase of rescue techniques taught to 20 rebreather divers with no previous experience in rescue techniques (6).

Based on this study, a lot of important considerations have been noticed, emphasizing the lack of rescue training for rebreather divers. This training should emphasize:

1. Simple and easy to remember techniques. In a real life emergency the technique is always more complex to perform and more difficult to remember, even if the rescuer practises it on a regular basis. Because of the inherent task-load experienced by any rebreather diver, a successful rescue tends to be more rare than its OC counterpart.

2. A protocol that is flexible enough to be used in most of the circumstances:

- <u>Any kind of recreational diving equipment</u> - dry suit or wet suit, Full-Face Mask (FFM) or usual half-mask.
- <u>Any kind of environment</u> - open water, flooded cave, ice, wreck penetration.
- <u>Any depth and breathing gas</u> - Deep Trimix dive with long decompression obligation, shallow no-decompression Nitrox dive.
- <u>Any kind of rebreather</u> – back-mounted or Over-the-Shoulder (OTS) counterlungs, Semi-Closed (SCR) and Closed Circuit Rebreathers (CCR), chest, back and side-mounted rebreathers, with or without Bailout Valve (BOV).

In the study cited in reference, one of the most important problems that has been noticed was the lack of priority during the rescue. In a recent rebreather fatality where the victim died and the rescuer was severely bent (severe symptoms of neurological decompression sickness), it has been emphasized that the most important factors of a rescue are:

1. The safety of the rescuer (like in any type of rescue, there is no reason why a potential fatality should end up in two fatalities) (7).
2. The most life-threatening problem for the victim. In most of the cases, drowning should be considered as the major threat. Hypoxia is also a very important issue. People can recover from decompression sickness (DCS) or even from Arterial Gas Embolism (AGE), not from complete drowning. In most situations, the most appropriate protocol is to bring the victim to the surface safely and as quickly as reasonable (3).

Cause of unconsciousness underwater

The reasons why people pass out underwater can be extremely various and complex. A large array of medical conditions can trigger unconsciousness at various levels of exertion and in various circumstances underwater or at the surface. These medical conditions should be screened and spotted during a fitness-to-dive medical exam (8). However some of them can stay undetected even by diving medicine experts.
Causes of unconsciousness can also result from diving-related problems such as (9):

- Cold (sudden or long exposure).
- Marine Life Injury (bite, sting, injection of toxin).
- Vomiting (seasickness, vestibular disorders, etc).
- Decompression Sickness and Pulmonary Barotrauma.
- Inert Gas Narcosis.
- Carbon Monoxide Toxicity.

Some rebreather-specific problems can also trigger physiological problems at the origin of a blackout (10) (11) (12):

- Hypercapnia (excess of CO_2).
- Hypoxia (lack of O_2).
- Hyperoxia (excess of O_2)

The initial cause of the unconsciousness is not really crucial and the rescuer shouldn't loose a lot of precious time to determine if they are dealing with Hypercapnia, Hypoxia or Hyperoxia. However Hyperoxia is a case on its own, as a convulsion could appear. Susceptibility to a high level of oxygen varies both between individuals and within the same person from day to day and the occurrence of convulsions might create additional problems and delays for the rescuer (13).

A grand mal convulsion generally occurs in three phases:
1. The 'Tonic' phase - a period of body rigidity. It is dangerous to attempt to surface the casualty at this stage because spasm of the glottis and respiratory muscles will result in inadequate exhalation and may therefore provoke pulmonary barotrauma. Fortunately this phase doesn't last more than a minute.
2. The 'Clonic' phase during which the casualty undergoes true convulsions. This can last for widely varying periods of time. Some studies and discussions with medical experts tend to show that the airway is not blocked at this stage.
3. The 'Post-Ictal' phase during which the victim rests and actually resumes breathing. Depending on the circumstances, the victim can "wake-up" and be confused, disoriented or even combative for quite a long time, or simply stay unconscious. Other convulsions may follow the first one, sooner or later (14).

Protocols

1. Stabilizing the victim in the water column.
It has been shown during a few rescue attempts that it might be extremely difficult to stop a free-falling unconscious rebreather diver in mid-water (15).

- If the diver is found unconscious close to the bottom, the rescuer should find a stable position on the bottom.
- If the diver is found unconscious in mid-water or during deco, the easiest technique used during the study has been to maintain the depth by grabing the ascent line.

Out of 57 rescue attempts performed during the evaluation phase of these protocols, all the rescuers have obtained very promising outcomes every time another diver, regardless of their level of training and experience, has helped them (6). So it's strongly recommended for the rescuer to try by all means to attract attention and get some help to:
- Send an emergency SMB to make the surface support aware of the situation (*in open water*).
- Go through restrictions or simply to take care of the navigation (*in a cave*).
- Remove the victim's gear and to provide first aid (*at the surface*).
- Control buoyancy and body position on the bottom and during the ascent.

2. Assessing the situation

The rescuer has to assess the victim, the equipment and the environment in order to determine the best course of action and if the ascent has to be immediate or slightly delayed. In any case this assessment should be quick and shouldn't delay the rescue but make it more efficient. The rescuer has to deal with a high level of stress, time pressure being quite important. The following elements have to be quickly assessed:

- The victim
- The equipment
- The environment

2.1 The victim

Is it an oxygen toxicity seizure? In case of a convulsion underwater, the dangerous part being the Tonic phase, the victim's depth has only to be kept constant at the very beginning (a few seconds up to one minute) (16). If the rebreather diver doesn't wear a FFM or a neck-strap that efficiently protects their airway, drowning is a major concern. Therefore the main priority is to bring the victim to the surface as soon as safely possible.

Is the victim breathing? If there is no obvious sign of breathing (no bubble, no chest movement, no movement of the counterlungs), it is of the utmost importance to bring the victim to surface to administer artificial respiration/Cardio-Pulmonary Resuscitation (CPR) (17).

2.2 The equipment

Does the diver wear a FFM or a neck-strap that efficiently protect their airway? If it's not the case, even if the diver has still their mouthpiece in place, risks of drowning are quite high, even if the rescuer tries to maintain the mouthpiece in place. Any delay in the ascent should be avoided.

Is the mouthpiece still in the mouth? If not, a rescuer shouldn't attempt to replace it but should rather ensure that the rebreather dive/surface valve (DSV) is switched to the surface position (closed) to avoid unnecessary loop flooding. The rescuer should try to seal the mouth and ascent immediately.

Is there any water in the mask? A partially or completely flooded mask could be a major problem for the victim's airway. If it's the case, several protocols suggest pinching the nose during the ascent (3).

Is the loop content safe to breathe? This is only a concern if the diver breathes and their airway is protected. The rescuer can check the pO2 readings to make sure that the victim will be able to breathe a safe mix during the ascent (18).

Hypoxia: checking the loop content during the ascent is crucial, as the pO2 will drop when ascending to the shallows.

Hyperoxia: Flushing the loop with diluent or switching to a Bailout valve (BOV) could be an option. However one should also consider that breathing a high O2 mix in the loop could be beneficial on a decompression standpoint. In case of Mixed-gas diving, the open-circuit (OC) mix has to be breathable all the way up to the surface and the amount of gas in the tank has to be sufficient.

Hypercapnia: Without a proper scrubber monitor, it will be difficult for the rescuer to assess the CO2 level in the loop but it's not a major issue anyway. A diluent flush will help in any case, as it could also help in case of a partial loop flood (19). Remember that, in order to efficiently flush the loop on most of the units, the rescuer has to open the overpressure valve (OPV) first.

2.3 The diving environment

Is there any physical problem that could delay the ascent? An overhead environment (cave, ice, wreck penetration) could delay the ascent as the rescuer will have to swim to the exit point.

A strong current in open water could also make the rescuer considering swimming to an ascent line rather than drifting far from the boat.

Is there any physiological concern that could delay the ascent? If a breathing victim with a properly protected airway (FFM, neck strap) has a significant decompression obligation, the rescue has to consider the possibility of performing the required stops to minimize the risks of DCS.

3. Ascending to the surface

If the victim doesn't breathe or doesn't have a properly protected airway, the ascent to the surface should be immediate (15).

However the rescuer could have a significant decompression obligation as well. In this case, three main options are available:

- Ascending with the victim at the surface, providing 1st aid or handing the victim over to the surface support, then eventually follow a missed deco procedure (3).

- Handing the victim over to another diver with no/less decompression obligation.
- Sending the victim to the surface on their own, hoping that the surface support will be efficient and fast enough.

Discussions with divers involved in rebreather diver rescues have shown that this is a personal decision, based on a lot of factors that have to be quickly considered by a highly stressed rescuer (20):
- The apparent state of the victim (not breathing since a very long time, etc).
- The amount of decompression obligation and the perceived risk of DCS.
- The accepted risk (that could depend on the relationship with the victim).
- The efficiency and the availability of the surface support.
- The surface condition (rough sea where the victim might not be seen by the boat crew, etc).

3.1 Opening and protecting the airway
The rescuer must definitely ensure that the victim's airway is open. This is easily done by holding the victim's mouthpiece in and keeping the neck slightly extended. However some studies show that an unconscious diver can hardly suffer from airway blockage and the related pulmonary barotrauma.

3.2 Controlling the ascent
It's often very difficult to keep control of the buoyancy of 2 divers at the same time, particularly in the shallows. Some techniques might make this phase easier:

- Inflating the victim's Buoyancy Compensator (BC) to start ascending.
- Opening the victim's loop OPV (and the dry suit purge if appropriate).
- Controlling the victim's BC purge.
- Controlling the rescuer's own buoyancy by emptying their BC, opening their dry suit purge if appropriate, and purging their own loop on the way up.

3.3 Establishing positive buoyancy at the surface
If the loop is not flooded, the main thing to do is to fully inflate the victim's BC, providing enough buoyancy to maintain the diver at the surface. The DSV should be closed when removed from the mouth to avoid loop flooding and loss of buoyancy at the surface (at the origin of several unsuccessful rescues). Depending on the equipment or if the loop is flooded, it may be necessary to release some weight or accessories (canister light, sling tank, etc).

3.4 Providing first aid
This means first care for the victim AND the rescuer:
- Calling for help. If no help is available, it may be necessary for the rescuer to stop for a few seconds to keep the stress level reasonable and assess the victim and the resources available at the surface.
- Ensuring the victim is breathing or initiating in-water artificial ventilation (17).
- Handing over the victim to the surface support or swim to the nearest platform available (boat, shore, etc) in order to provide better care (CPR/1st aid/emergency O2).
- Arranging for evacuation (nearest chamber/ diving physician).

Discussion

During this study, the authors discovered several potential problems further complicating the rescue of an unconscious rebreather diver.

- Some divers with open-circuit technical diving background have sometimes been trained to remove a regulator supplying a hyperoxic mix to replace it by another regulator (21). This procedure shouldn't be applied to unconscious rebreather divers because of the unnecessary delay to do so and the risk of flooding the rebreather loop. Furthermore opening the mouth to put in a regulator might only achieve water introduction/drowning. Some rescuers feel confident in attempting to seal a second stage with a breathable mix against the lips in the hope that if breathing resumes air will be inspired instead of water. The authors believe that none of these actions should delay the ascent or compromise the efficiency of the rescue.

- In case of a malfunctioning unit (leaking solenoid, ADV, manual injector, BCD inflator, etc), it may be difficult for the rescuer to quickly find out if there is a leak, where it comes from and how to stop it. The rescuer has to be aware that the rescue could end up in an uncontrolled ascent with missed decompression stops and higher risk of DCS. The risks inherent to a rescue should be fully understood and accepted by the rescuer. These risks should be explained in a rebreather-oriented rescue training program, along with the appropriate missed-decompression procedures (3).

A few studies have been done to fully understand the mechanisms of rebreather accidents (22) (23). However more information are needed to encompass the large array of circumstances of recreational rebreather rescues.

Conclusion

Even if most of the training agencies and official bodies dealing with recreational rebreather diving all agree on the lack of safety related to solo rebreather diving, this kind of practice is still very popular. The authors came to the conclusion that to increase the chances of survival in case of rebreather-related accidents occurring underwater or at the surface, there are several needs to fulfil:

- Need for a buddy. To quote Carl Edmonds (11): " *The practice of Buddy diving is the single most important factor in rescue. It requires that each diver is responsible for the welfare and safety of his companion*". Training simulations have shown Open Circuit rescuers to be as efficient as Rebreather rescuers, if the rescue protocols to follow are clear enough.
- Need for proper team procedures. A buddy too far away and not aware of the situation is almost as useless as no buddy at all. Having a buddy ready to perform a rescue means that the team is not spread over a long distance on the bottom or during the decompression phase of the dive and follow real team procedures (effective communication, constant buddy check, etc).
- Need for proper training. A well-trained buddy has usually more chances to perform an efficient rescue than an un-trained one, even when dealing with a high stress load (20).
- Need for proper safety equipment. Some accessories can definitely help in case of a rescue situation (FFM or neck-strap as individual protection, shotline and SMB in open water, etc).

References

(1) "Proceedings of Rebreather Forum 2.0", M. Menduno, Diving Science and Technology, USA
(2) "NOAA Diving manual: diving for science and technology", S. Spring, NOAA Office of Undersea Research, USA
(3) "US Navy Diving Manual" vol. 4, Naval Sea System Command, USA
(4) "NDC Diving Incidents Reports" (1999 to 2007), B. Cumming, British Sub-Aqua Club
(5) "Annual Diving Report" (2001 to 2007), N. Pollock and al, Divers Alert Network
(6) "DIRrebreather Rescue Workbook", C. Verdier, DIRrebreather
(7) "The Encyclopedia of Technical Diving" T. Mount, International Association of Nitrox and Technical Divers
(8) "Fitness for Diving" Alert Diver European Edition, Divers Alert Network
(9) "Diving and Subaquatic Medicine" 4th Edition, C. Edmonds, C. Lowry, J. Pennefather, R. Walker, Arnold publishing, UK
(10) "The Prevention and Management of Diving Accidents" (revised October 1997), Royal Navy Institute of Naval Medecine, Report No. R97066, UK
(11) "The Story of CO2 Build-up" Rev. E. Lanphier
(12) "Carbon Dioxide and the Rebreather Diver", H. Packer
(13) "Oxygen and the Diver", K. Donald, Best Publishing Co., USA
(14) "Current Thoughts on Mechanisms of Hyperoxic Seizures", J. Brian, University of Iowa Hospitals and Clinics
(15) "Private correspondence with 3 rescuers of rebreather divers", (France, Hong-Kong and UK)

(16) “Glottal patency during experimental cortical seizures in piglets”, Leaming, Academic Emergency Medicine
(17) “PADI Rescue Diver Manual”, Professional Association of Diving Instructors, USA
(18) “Performance of Diving Equipment”, Research report 424, Health and Safety Executive, UK
(19) "ANDI - Recreational Diving with Closed-Circuit rebreathers", E. Betts, American Nitrox Divers International, USA
(20) "Stress and performance in diving", A. Bachrach, E. Egstrom, Best Publishing Co., USA
(21) “Oxygen Toxicity protocol”, S. Hunsucker, Woodville Karst Plain Project, USA
(22) “Rebreather Fatality Investigation”, R. Vann, R. Pollock, P. Denoble, Divers Alert Network
(23) “Compilation of Technical Diving Incident Database”, J. Bozanik
(24) “Technical Diving, too far too soon?” J. Bozanik

Appendix: Rebreather Rescue Flowchart