Recommendations for rescue of a submerged unresponsive compressed-gas diver

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ABSTRACT

The Diving Committee of the Undersea and Hyperbaric Medical Society has reviewed available evidence in relation to the medical aspects of rescuing a submerged unresponsive compressed-gas diver. The rescue process has been subdivided into three phases, and relevant questions have been addressed as follows.

Phase 1, preparation for ascent: If the regulator is out of the mouth, should it be replaced? If the diver is in the tonic or clonic phase of a seizure, should the ascent be delayed until the clonic phase has subsided? Are there any special considerations for rescuing rebreather divers?

Phase 2, retrieval to the surface: What is a "safe" ascent rate? If the rescuer has a decompression obligation, should they take the victim to the surface? If the regulator is in the mouth and the victim is breathing, does this change the ascent procedures? If the regulator is in the mouth, the victim is breathing, and the victim has a decompression obligation, does this change the ascent procedures? Is it necessary to hold the victim's head in a particular position? Is it necessary to press on the victim's chest to ensure exhalation? Are there any special considerations for rescuing rebreather divers?

Phase 3, procedure at the surface: Is it possible to make an assessment of breathing in the water? Can effective rescue breaths be delivered in the water? What is the likelihood of persistent circulation after respiratory arrest? Does the recent advocacy for "compression-only resuscitation" suggest that rescue breaths should not be administered to a non-breathing diver? What rules should guide the relative priority of in-water rescue breaths over accessing surface support where definitive CPR can be started?

A "best practice" decision tree for submerged diver rescue has been proposed.

INTRODUCTION

The Diving Committee of the Undersea and Hyperbaric Medical Society (UHMS) acts as a bridge between the members of the Society and divers. The Committee is occasionally asked to address a specific question of practical significance to divers, but which requires scientific or medical interpretation, and to make recommendations to the diving community.

This paper is a Diving Committee initiative to address the medical aspects of rescue and resuscitation of an unresponsive diver. This initiative was prompted by requests from diver training agencies who wish to revise training material and by specific questions from the scientific diving community. There is ongoing debate over the optimal approach to rescue of an unresponsive diver from depth. There is a paucity of related research, and this means that any recommendations on rescue technique will defer largely to "expert opinion."

Nevertheless, the UHMS Diving Committee is an appropriate resource to consider relevant questions and promulgate recommendations. Indeed, with the exception of the South Pacific Underwater Medicine Society Policy on Initial Management of Diving Injuries and Illnesses [1] (which is now 14 years old and addressed in-water rescue only superficially) there is a conspicuous absence of recommendations from expert groups in relation to this matter.

SCOPE OF THE REVIEW

This review addresses the course of action on finding an unresponsive diver underwater in circumstances either where the disabling event was witnessed or where the period of unresponsiveness is uncertain and resuscitation must therefore be considered possible. Thus, it does not apply to "body recovery," where resuscitation will not be attempted. The focus is on diver rescue.

Methods of resuscitation *per se* are not discussed except where they have implications for the conduct of the in-water phase of the rescue; neither is post-resuscitation care discussed. This review considers only compressed-gas bounce dives (dives in which the duration from leaving to returning to surface is on the order of minutes or hours) and dives conducted using a half-face mask and separate mouthpiece. The principal focus is on recreational diving using open circuit "scuba" equipment supplying air, or occupational diving using similar equipment configurations.

Some of the controversies considered are also relevant to recreational "technical diving," in which gases other than air and equipment such as rebreathers are customarily used, and in which decompression dives are commonly performed. Advanced occupational scenarios such as diving with helmets and surface-supplied gas, saturation diving, and bell diving are not discussed.

For the purpose of this review a "rescuer" is a diver who has received specific training in diver rescue. This is appropriate given that this review is largely a response to questions about the content of such training. There is no attempt to define appropriate practice for divers who have not received training in rescue techniques.

Finally, the purpose of this paper is to address certain medical aspects of diver rescue; and particularly those that cause controversy. It does not address mechanical details of practical rescue techniques (methods of buoyancy control during ascent, for example) unless there is particular relevance to a medical consideration. The prescription of practical techniques is left to the respective diver training agencies. As a basis for discussion, this paper will refer to the methods recommended in the Professional Association of Diving Instructors (PADI) Rescue Diver Manual [2].

METHODS

The key steps in the rescue of an unresponsive diver were defined, and a set of important questions in relation to those steps were generated. Two members of the diving committee (SJM, MHB) reviewed the relevant literature and drafted responses to these questions. These were distributed to participating committee members for discussion. All participating members were invited to submit comments, and where necessary, these were discussed prior to modification of the recommendations. It can be assumed that recommendations made in this paper that are not referenced to external sources of evidence represent the consensus opinion of the listed authors from the UHMS Diving Committee. The overall content is endorsed by the committee. It should be noted that no participating members were employees of a diving training organization, nor were there any other potential conflicts of interest. The finalized recommendations were submitted for consideration by the UHMS Publications Committee, and for peer review and publication in *Undersea and Hyperbaric Medicine*.

KEY STEPS IN DIVER RESCUE AND RELATED QUESTIONS

It is universally agreed that on finding an unresponsive diver underwater the overarching priority should be to retrieve the diver to the surface and initiate resuscitative measures as quickly as practicable while avoiding harm to the rescuer. This process can be broken down into three phases:

- preparation for ascent;
- retrieval to the surface; and
- procedures at the surface.

Preparation for ascent

When an unresponsive diver is found at depth the rescuer will take steps to position the victim appropriately and initiate an ascent while controlling buoyancy and maintaining his/her own safety. The PADI Rescue Diver Manual [2] states that if the regulator is in the mouth it be held there throughout the ascent. The committee identified the following relevant questions:

1. If the regulator is out of the mouth, should it be replaced?
2. If the diver is in the tonic or clonic phase of a seizure, should the ascent be delayed until the clonic phase has subsided?
3. Are there any special considerations for rescuing rebreather divers?

Retrieval to the surface

During the ascent the PADI Rescue Diver Manual [2] recommends the rescuer maintain a "safe" ascent rate and holds the victim's head in a neutral position. The committee identified the following relevant questions:

1. What is a "safe" ascent rate?
2. If the rescuer has a decompression obligation, should he/she take the victim to the surface?
3. If the regulator is in the mouth and the victim is breathing, does this change the ascent procedure?
4. If the regulator is in the mouth, the victim is breathing and the victim has a decompression obligation, does this change the ascent procedure?
5. Is it necessary to hold the victim's head in a particular position?
6. Is it necessary to press on the victim's chest to ensure exhalation?
7. Are there any special considerations for rescuing rebreather divers?

Procedure at the surface

Once at the surface the PADI Rescue Diver Manual [2] instructs as follows: The diver be positioned face-up, and positive buoyancy be established for both victim and rescuer. A call for help should be made and the victim's airway opened followed by rescue breathing if there is no spontaneous respiration.

After two breaths with no victim response, the manual prescribes evaluation of distance from surface support. If surface support is less than five minutes away, intermittent rescue breaths should be continued while towing the victim until surface support is reached and the diver is removed from the water (at which time a cardiopulmonary resuscitation [CPR] protocol should be initiated).

If surface support is more than five minutes away the rescuer should remain where he/she is and provide rescue breaths for one minute and check for response. If there is no response the rescuer should assume that cardiac arrest has occurred and tow the victim to surface support as quickly as possible without rescue breaths, remove the victim from the water, and initiate a CPR protocol. The committee identified the following relevant questions:

1. Is it possible to make an assessment of breathing in the water?
2. Can effective rescue breaths be delivered in the water?
3. What is the likelihood of persistent circulation after respiratory arrest?
4. Does the recent advocacy for "compression-only resuscitation" suggest that in-water rescue breaths should not be administered to a non-breathing diver?
5. What (if any) rules should guide the relative priority of in-water rescue breaths over accessing surface support where definitive CPR can be started?

COMMITTEE DETERMINATIONS ON CONTROVERSIES

Before addressing the specific controversies, the committee felt that several general comments in relation to diver rescue were appropriate. First, any diver who becomes unresponsive underwater is in a perilous situation. All divers must understand that even a textbook rescue will frequently not achieve a good outcome. Interpretations of accidents and any commentary on the outcome of attempted rescues should therefore be made with great caution.

Second, there are many contextual issues that could influence the correct course of action in any particular situation. Although best evidence, logic and experience have been applied in answering the questions posed in the previous section, it is not claimed that these answers will invariably be correct in all situations.

PREPARATION FOR ASCENT

If the regulator is out of the mouth, should it be replaced?

There is no relevant evidence to guide discussion on this question. It was the committee's consensus that no attempt should be made to replace a dislodged regulator even in a witnessed loss of consciousness, except in an overhead environment, where there is no option for a direct ascent and where the victim's only hope is resumption of spontaneous ventilation underwater (a virtually unsalvageable scenario). In such a case the regulator should be purged before replacement.

Manipulating the airway risks the entry of water, and any advantage is uncertain. In particular there was doubt that a regulator held in place would protect the airway any more than a mouth held closed. There was general agreement that if the regulator remained in the mouth at the time the diver was discovered, an attempt should be made to keep it there, especially if the victim still appears to be breathing.

If the diver is in the tonic or clonic phase of a seizure, should initiation of the ascent be delayed until the clonic phase has subsided?

There is a long-standing belief that if a diver suffers a generalized convulsion underwater he/she should be held at a fixed depth until the clonic phase of the convulsion has subsided. Although there are minor variations, this is generally reflected in relevant recommendations in the U.S. Navy Diving Manual [3]. This advice is based on the notion that the glottis will spasm shut during a convulsion and that the diver would therefore trap expanding gas in the lungs during ascent, leading to pulmonary barotrauma.

There are several reasons to critically review this concern. First, as many emergency physicians know, patients suffering prolonged generalized convulsions actually do ventilate the lungs, and can also be ventilated with a bag and mask. It thus appears that glottal obstruction in this condition is partial rather than total.

Second, a study by Leaming *et al.* [4] using video-laryngoscopy in pigs during generalized seizures appeared to suggest that airway obstruction was primarily inspiratory, and that glottal patency at the onset of expiration was relatively normal.

Finally, the end of the clonic phase may be marked by resumption of deep breathing, and during immersion with an unprotected airway this would almost certainly result in drowning.

Taken together, one interpretation of these observations is that the clonic phase of a convulsion (prior to resumption of coordinated breathing) is actually an appropriate time to bring the victim to the surface. However, this matter deserves cautious interpretation. The observations of glottal patency by Leaming were of such interest that two committee members (RW, REM) obtained the original video-loops made during the experiments. Careful study of these videos suggests closure of the glottis throughout the seizure periods recorded, with no clear opening on expiration. It is not possible to interpret the degree to which expiration is obstructed from this observation but it does raise concerns about wholesale abandonment of the current recommendation.

It follows from the above that the committee's determination is as follows: If a compressed-gas diver is discovered in the clonic phase of a seizure at depth and the regulator is not in the mouth the diver should be retrieved to the surface without delay. If the regulator is in the mouth, then every attempt should be made to hold it in place while sealing the lips around the mouthpiece; surfacing should be delayed until the seizure has resolved.

This recognizes the committee's perception that without the regulator in place, drowning on resumption of breathing probably represents the greatest threat to life, and with the regulator held in place, pulmonary barotrauma during an ascent with a closed glottis becomes the greater concern.

Are there any special considerations for rescuing rebreather divers?

If the mouthpiece is out of the mouth, the committee could see no reason to depart from the generic rescue recommendations contained elsewhere in this paper. No attempt should be made to replace the mouthpiece, and ascent should be initiated immediately. If the mouthpiece and mask are in place then it is possible the diver is breathing. For this scenario, specialist groups providing rebreather instruction may consider adapting the following principles to an algorithm specific to the devices they teach.

First, attempt to retain the mouthpiece in place and seal the lips around it as well as is practicable. Assume that the diver is breathing, and expend no time trying to verify this.

Second, if the rebreather has a pO_2 monitor and the rescuer is familiar with the victim's unit, check the loop pO_2. Hyperoxia (pO_2 > 1.6 atm abs) should be ignored and ascent initiated unless the diver is actively convulsing, in which case the rescuer should wait until the seizure has finished before ascending. Hypoxia (pO_2 < 0.2 atm abs) should be corrected by manually adding oxygen into the loop. Gross hyperoxia should be avoided, but time should not be wasted in an attempt to titrate the pO_2 to a particular level beyond establishment of normoxia or even mild hyperoxia (since the pO_2 will fall during ascent).

If there is no pO_2 monitoring (either because it is not a feature of the rebreather or due to loss of electronics) a flush of diluent to "fill" the loop will, under most circumstances, ameliorate both loop hypoxia and hyperoxia to some extent. It will also help establish positive buoyancy (that will not subsequently change if the loop is filled) to begin the ascent.

These recommendations for checking pO_2 and taking corrective action are broadly confluent with those prescribed by the U.S. Navy [3]. If the rescuer is unfamiliar with the rebreather, the rebreather oxygen or diluent supplies are exhausted, or there are any other logistical barriers to performing a simple "check and correct," as described here, within 10 to 20 seconds, then no more time should be expended on attempts to manipulate the loop gas composition, and an ascent should be initiated.

RETRIEVAL TO THE SURFACE

What is a safe ascent rate?

This question was raised because a "safe ascent rate" is referred to (but not defined) in the PADI Rescue Diver Manual [2]. The committee felt there was no generic answer to this question. Indeed, for the victim, the safest ascent rate is likely to be "as fast as possible" in many cases and will almost invariably be faster than a safe rate for the rescuer. Moreover, prescribing an actual rate invites a potentially unhelpful fixation on trying to adhere to it. In reality, a rescuer would be doing well just to maintain a reasonably controlled ascent. The "safe ascent rate" is a context-sensitive matter for the rescuer to determine.

If the rescuer has a decompression obligation, should he/she take the victim to the surface?

For the purposes of this discussion, the committee considered that the practice of inserting a "safety stop" during ascent from a "no-decompression dive" does not represent a "decompression obligation." With that acknowledged, it is a general principle of emergency response that first responders should not put themselves at unreasonable risk in order to effect a rescue. Although omitting decompression stops will not invariably result in DCS, the presence of a significant decompression obligation and a consequent risk of DCS with a direct ascent could certainly be construed as unreasonable risk.

History tells us that rescuers may be prepared to expose themselves to such risk [5,6] but also that they may injure themselves doing so [6]. The difficulty in defining "unreasonable risk" and the myriad factors that can influence it in any practical diving situation make it impossible for the committee to say anything other than it is acceptable for rescuers to avoid exposing themselves to risk.

Risk acceptance in these situations is a personal matter for the rescuer. In the event that a rescuer elects not to bring a victim to the surface, there is little choice other than to make the victim positively buoyant and let that person go. This strategy has been used successfully in at least one technical diving accident occurring at extreme depth; the victim survived because the surface support crew was vigilant, saw him arrive at the surface and were able to retrieve and resuscitate him [7].

If the regulator is in the mouth and the victim is breathing, does this change the ascent procedure?

There was no relevant evidence to guide discussion on this question, but it was the committee's consensus that the primary goal should still be to get the diver to the surface as quickly as possible – accompanied and managed by the rescuer. If the regulator is in place and the diver is breathing, this increases the importance of retaining the regulator in the mouth and sealing the lips around the mouthpiece as well as practicable.

If the regulator is in the mouth, the victim is breathing and the victim has a decompression obligation, does this change the ascent procedure?

It is reiterated that for the purposes of this discussion the committee considered that the practice of inserting a "safety stop" during ascent from a "no-stop dive" does not represent a "decompression obligation."

As a general rule it was considered that it would be very difficult to protect and manage the airway in an unresponsive diver for long enough to complete any meaningful decompression stops. Any attempt to do so might result in drowning, which, depending on the amount of omitted decompression, would likely represent a greater threat to life than decompression sickness (DCS) arising from a direct ascent.

It is acknowledged that there is anecdote describing successful airway management underwater. In one event that followed an oxygen convulsion at a 12-meter decompression stop, a rescuer held an open-circuit scuba regulator in place while bringing the victim to the surface over six minutes [5]. It is notable that the rescuer in this event was a highly experienced technical diver.

It is evident that under some circumstances the airway could be protected adequately to allow a period of decompression under ideal conditions, and this would be even more likely if the victim were using a full face mask or a properly designed and deployed mouthpiece-retaining device. Any decision to attempt this would depend entirely upon context, and it is reiterated that the path of least risk in the majority of circumstances will be to bring the victim directly to the surface.

Is it necessary to hold the victim's head in a particular position?

The object of head positioning for ascent is to facilitate the escape of expanding gas from the victim's lungs in order to avoid pulmonary barotrauma. Thus, any position that tends to close the airway, such as extreme flexion of the neck, should be avoided. The committee consensus is that the neck should be held in a neutral to slightly extended position, if possible. Based on cases in which the authors have been involved and where unresponsive divers have been recovered from moderate depths, it appears that expanding gas passes passively out of the airway and pulmonary barotrauma is rare. As a sidebar to this discussion, this expansion and outward flow of gas during ascent may help prevent aspiration of water into the lungs.

Is it necessary to press on the victim's chest to ensure exhalation?

Compression of the chest during ascent to promote exhalation and thereby minimize the risk of pulmonary barotrauma has featured in previous diver rescue recommendations. There is no evidence that it is more effective in preventing barotrauma than merely ensuring the airway is patent: Its principal disadvantage is that it potentially "task loads" the rescuer who may simultaneously be trying to control buoyancy, maintain appropriate head position, and possibly ensure retention of a regulator.

The committee does not recommend this technique.

Are there any special considerations for rebreather divers?

In an ascent with mouthpiece retained, the rescuer should avoid dislodging the mask or firmly blocking the nose in any way. The mask will prevent water entering the nose, but expanding gas in the rebreather loop will still be able to escape by that route. Depending on the rebreather configuration, this may be important for avoiding lung barotrauma.

The rescuer should not attempt to manipulate the gas composition of the loop while trying to control the ascent.

PROCEDURE AT THE SURFACE

Is it possible to make an assessment of breathing in the water?

It is acknowledged that there may be difficulty with assessing breathing under some circumstances, but the most likely error would be failure to detect breathing when it is present rather than to perceive breathing when it is absent. Since it seems unlikely that harm would accrue from attempting to administer rescue breaths to someone who is already breathing, the rescuer should not hesitate to deliver rescue breaths as recommended below if there is any suspicion that the victim is not breathing.

Can effective rescue breaths be delivered in the water?

This question was directly addressed by a study in which trained lifeguards demonstrated delivery of effective rescue breaths (average tidal volumes by individual lifeguards from 629-750 ml) while unsupported in deep water [8]. In this same experiment, the delivery of seven to nine breaths over a 50-meter victim (manikin) tow increased the duration of the tow from 70 seconds to 84 seconds (on average).

It thus seems clear that effective rescue breaths can be delivered in deep water. Divers would be more cluttered with equipment than the lifeguards in this experiment, but on the positive side, they are also supported by buoyancy devices and wearing fins. The experience of several members of the committee exposed to rescue diver training is consistent with the results of the experiment. The committee thus has little hesitation in endorsing in-water rescue breaths as a plausible technique, but the likelihood of successful delivery is dependent on prior training (and preferably regular practice) in the technique.

What is the likelihood of persistent circulation after respiratory arrest?

It is well recognized that there may be a variable interval between respiratory and cardiac arrest, and that this is context-sensitive [9]. The question is therefore impossible to answer in a definitive way. There is some evidence from individual cases that the interval can be of practical significance. For example, the previously cited resuscitation of three non-breathing divers without defibrillation or intervention with cardiac drugs [5-7] implies persisting circulation following an apneic period measured in minutes.

Similar inference can be drawn from a small but unique observational study by Szpilman and Soares [9] in which drowning victims who received in-water expired air resuscitation were less likely to require full CPR or any other additional resuscitation measures than victims who were retrieved from the water prior to any intervention.

The committee therefore endorses the view that in a dive accident leading to respiratory arrest there is likely to be a variable window of opportunity within which commencement of expired air resuscitation may prevent progression to full cardiac arrest.

Does the recent advocacy for "compression-only resuscitation" suggest that in-water rescue breaths should not be administered to a non-breathing diver?

Discussion of "compression only resuscitation" (in which first responders administer only chest compressions and do not attempt rescue breathing) has occurred over many years. Recent publications suggesting its superiority over "conventional" CPR in certain circumstances have created significant interest in the diving community.

Three studies in which subjects suffering out of hospital cardiac arrest were randomized to compression-only resuscitation or conventional CPR by an emergency dispatcher who instructed untrained first responders (by phone) in undertaking one technique or the other were entered into a meta-analysis [10]. This showed a small but significant increase in survival (absolute increase 2.4%, number needed to treat = 41) if compression-only resuscitation was used. These studies excluded cases in which there was intervention by bystanders trained in CPR, and consequently, the meta-analysis has been criticized as simply demonstrating that it is "not possible to teach untrained laypersons chest compressions in combination with ventilation via the telephone in an emergency" [11]. A meta-analysis of non-randomized observational cohort studies showed no advantage for either technique. [10] However, one large cohort study published subsequently did suggest a survival advantage for compression-only resuscitation [12] but this was in the context of both a concerted regional publicity campaign favoring the latter, and a consequent massive swing away from the use of conventional CPR. The interpretation of apparent benefit deserves cautious analysis.

There are plausible advantages for compression-only resuscitation, including:

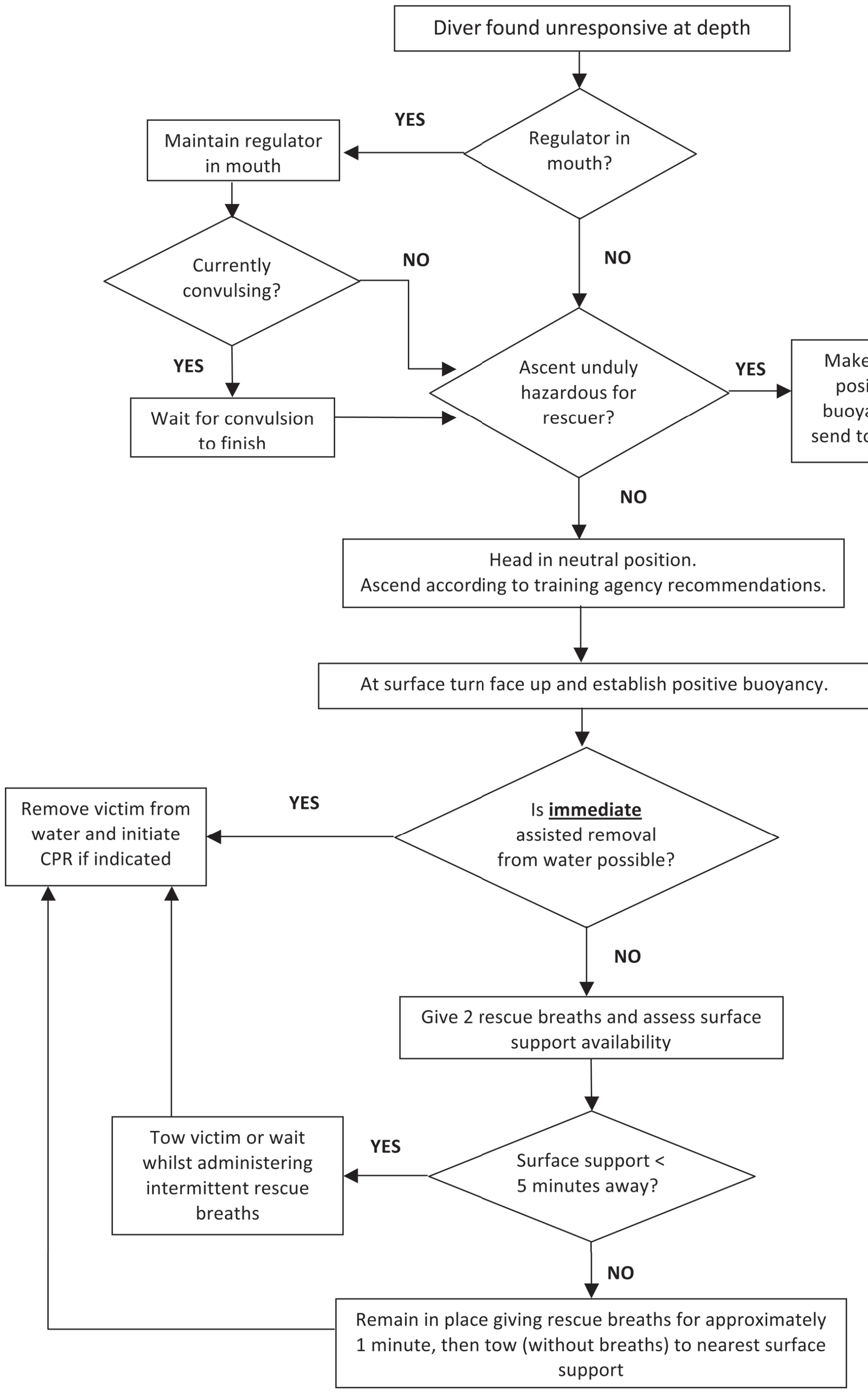
- eliminating hesitancy by rescuers who are uncomfortable using mouth-to-mouth techniques;
- avoiding deterioration of forward flow during pauses to deliver rescue breaths;
- avoiding the flow inertia that prevails after such pauses;
- avoiding the reduction in venous return that may occur with positive-pressure ventilation; and others. [12].

However, all of these, and indeed the results of the outcome studies in out-of-hospital cardiac arrest (where collapse and cessation of breathing is frequently due to the cardiac arrest itself), are of uncertain relevance to the diving situation, where respiratory arrest is more likely to be due to asphyxia, and where there may be a significant interval before cardiac arrest, as discussed above.

Therefore, in divers, rescue breaths may prevent progression to cardiac arrest. Not surprisingly, commentators representing expert groups have argued that in drowning victims the correction of hypoxia is the first priority [13], and failure to provide ventilation to the victim may jeopardize outcome [14].

On this basis, the committee believes that the current advocacy for compression-only resuscitation in community cardiac arrest may not be relevant to diver rescue situations. The committee therefore recommends rescue breathing as prescribed in Figure 1 *(Page 1106)*. It remains true that the underlying cause of the respiratory arrest is a crucially important factor in determining the likelihood of successful resuscitation.

FIGURE 1 – Rescue breathing protocol



Summary of important recommendations and decision-making in rescue of an unresponsive diver from depth. This chart should be considered along with the relevant comments made in the relevant sections of this paper.

In the rescue of a non-breathing diver how should the rescuer prioritize delivery of in-water rescue breaths versus accessing surface support where definitive CPR can be started?

The unresponsive non-breathing diver is either in a state of respiratory arrest or cardiorespiratory arrest, and the committee believes there is no reliable means of separating these states in water. Rescue breaths alone are unlikely to benefit a victim in full cardiorespiratory arrest, and effective chest compressions cannot be administered in the water. Therefore, any delay in removing the immersed victim to a stable platform allowing full CPR in order to deliver in-water rescue breaths is, in effect, a gamble on the possibility that they are in respiratory but not cardiac arrest.

As discussed above, the committee believes this gamble is worth taking at least in part because, in the absence of early paramedic-level advanced life support, a successful resuscitation from cardiac arrest is extremely unlikely, regardless of management. Nevertheless, there is a need for guidance on when to shift the priority from attempting rescue breaths to removing the victim from the water. The committee considered two key questions in this regard.

The first is whether there is any situation, other than concern about personal safety or an inability to deliver rescue breaths efficiently, in which a trained rescuer would not attempt in-water rescue breaths at all in favor of removing the victim from the water as quickly as possible.

One plausible circumstance might be when rescuer and victim surface immediately adjacent to suitable surface support such that there would be no delay at all initiating assisted retrieval. A relevant observation from actual incidents that have involved members of the committee is that removal of a fully equipped unresponsive scuba diver from the water is difficult and can take minutes.

Moreover, committee members have participated in rescues where resumption of breathing has occurred immediately on delivery of the first rescue breath. This supports the recommendation for delivery of initial rescue breaths as quickly as possible. However, the "breathe or remove from water decision" is very context-sensitive, so the committee is reluctant to recommend directive "rules" around these situations.

Its view on the matter is best summed up by the statement: "Even when surfacing immediately adjacent to surface support, a trained rescuer should consider positioning the victim on the back, establishing positive buoyancy, opening the airway, and delivering two rescue breaths before initiating attempts to remove the victim from the water. However, these steps can be set aside if circumstances suggest that removal of the victim from the water can be expedited in less than one minute."

Second, what should be done if surface support is not immediately available on surfacing? The committee believes that the advice in the PADI Rescue Diver Manual [2] is logical and consistent with the recommendations of the European Resuscitation Council [13]. Thus, on surfacing, initial rescue breaths are given as above. Then, if surface support is less than approximately five minutes away, intermittent rescue breaths should be continued while towing the victim (or waiting) until surface support is reached/arrives and the diver is removed from the water. CPR can then be initiated if it is determined that there is a concomitant cardiac arrest. If at any time during the tow the rescuer feels that delivery of rescue breaths is becoming too difficult or causing excessive delay, he or she should reduce the frequency of rescue breaths or omit them entirely.

If surface support is more than five minutes away the rescuer should remain where he/she is and provide rescue breaths for approximately one minute and then check for response. If there is no response, the rescuer should assume that cardiac arrest has occurred and tow the victim to surface support as quickly as possible without rescue breaths, remove the victim from the water, and initiate a CPR protocol supplemented, if possible, by high fractions of inspired oxygen.

SUMMARY OF RECOMMENDATIONS

We have generated a diver rescue algorithm which summarizes the important recommendations made in this paper *(Figure 1)*. Readers are reminded that in the absence of relevant definitive data, many of these recommendations are based on the consensus opinion of experts.

The committee also re-emphasizes several other key contextualizing comments: First, application of this pathway is contingent on appropriate diver rescue training. Second, it is entirely appropriate for rescuers to avoid causing harm to themselves in applying these rescue strategies. Third, recent changes in protocols for community cardiac arrest are of doubtful relevance to diver rescue interventions. Fourth, it is acknowledged that there may be circumstances in diver emergencies that are not adequately accounted for in these recommendations. It is difficult to provide a universally applicable guideline without the risk of it being hopelessly overcomplicated. These recommendations should not be seen as immutable rules for all situations.

Finally, it is reiterated that rescue and resuscitation of an unresponsive diver from depth is frequently unsuccessful. Notwithstanding this attempt to optimize current advice, unresponsive divers rescued from depth have a poor prognosis.

Acknowledgments

The committee thanks Professor Tom Terndrup for providing the raw video-laryngoscopy loops from his study of glottal patency during generalized seizures in pigs [4].

REFERENCES

1. Gorman D, Richardson D, Davis M, Moon R, Francis J. The SPUMS policy on initial management of diving injuries and illnesses. SPUMS J. 1997; 27:193-196.

2. Richardson D (Editor in Chief). Rescue Diver Manual. Rancho Santa Margarita, CA: Professional Association of Diving Instructors, 2006.

3. U.S. Navy Diving Manual Rev 6.. Washington DC: Department of the Navy, 2008.

4. Leaming JM, Terndrup TE, Ognibene S. Glottal patency during experimental cortical seizures in piglets. Acad Emerg Med. 1999 ;6:682-687.

5. Haaja J. O2 Convulsion discussion thread. http://www.rebreatherworld.com/rebreather-accidents-incidents/1632-o2-convulsion.html last accessed 6 April 2012.

6. Jackson T. Changing the outcome: anatomy of a serious diving accident. http://www.diveoz.com.au/regular_articles/readit.asp?p=3&a=21 last accessed 6 April 2012.

7. Trytko B, Mitchell SJ. Extreme survival: a deep technical diving accident. SPUMS J. 2005; 35:23-27.

8. Perkins GD. In-water resuscitation: a pilot evaluation. Resuscitation. 2005; 65:321-324.

9. Szpilman D, Soares M. In-water resuscitation – is it worthwhile. Resuscitation. 2004; 63:25-31.

10. Hupfl M, Selig HF, Nagele P. Chest-compression-only versus standard cardiopulmonary resuscitation: a meta-analysis. Lancet. 2010; 376:1522-1524.

11. Bottiger BW, Koster RW, Bossaert L. Chest-compression-only versus standard CPR (letter). Lancet. 2011; 377:716.

12. Bobrow BJ et al. Chest compression-only CPR by lay rescuers and survival from out-of-hospital cardiac arrest. JAMA. 2010; 303:1447-1454.

13. Soar J, Perkins GD, Abbas G et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 8. Cardiac arrest in special circumstances: Electrolyte abnormalities, drowning, accidental hypothermia, hyperthermia, asthma, anaphylaxis, cardiac surgery, trauma, pregnancy, electrocution. Resuscitation 2010; 81: 1400-1433.

14. Perkins GD, Handley AJ. Chest-compression-only versus standard CPR (letter). Lancet. 2011; 377:716.