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Drew Richardson is Vice-President Training, Education and Memberships, PADI International. His address is PADI International, 1251 East Dyer Road, # 100, Santa Ana, California 92705, U.S.A.

Terry Cummins is Chief Executive Officer, PADI Australia. His address is P.O.Box 713, Willoughby, New South Wales 2068, Australia.

A MEDICAL VIEW OF EMERGENCY ASCENT TRAINING.

John Knight and Guy Williams

Introduction

This paper is an attempt to use logic to discover what, if any, is the benefit of the present training in emergency ascents. We ask a number of questions. We also provide the answers and draw conclusions from the evidence. In this way I hope that everyone will be able to see past their fixed opinions and view emergency ascent training in a new light. One that allows impartial weighing of the benefits and costs of the various methods used today with students.

Why does a diver do an emergency ascent ?

The answer is simple. The diver is either out of air or injured. In both cases he or she needs to get to the surface as soon as possible.

What does the diver need from an emergency ascent ?

To arrive at the surface, preferably conscious. At the surface there is air to breathe, and, we hope, someone to rescue the diver. Failing to reach the surface is certain death.

Are emergency ascents always successful ?

No, they are not. Unfortunately, far too often the diver does not reach the surface, or sinks again after reaching it, and the body is recovered from the bottom with the weight belt still on.

Whatever method of emergency ascent is used there should be no possibility of failing to reach the surface. This involves the diver increasing his, or her, buoyancy. When one is out of air there is only one way to do this. Drop the weight belt and start what will eventually become a buoyant ascent, if one is wearing a wet suit or buoyancy compensator.

This is the best survival technique, which is carefully NOT practiced because it can result in an uncontrolled ascent.

Is there much need for emergency ascents ?

Most out of air problems are the diver's fault. Better air management would prevent most out of air situations. It would also prevent the usual precursor of an out of air problem, being low on air. No one dives these days without a contents gauge. So no diver should have air problems, if he or she is monitoring the air supply, unless there is an equipment failure and these are rare in Australasia.[1,2]

However it is clear from Bob Halstead's survey that experienced divers do have to make emergency ascents.[3] Approximately one third of his divers had had to make an emergency ascent because they ran out of air and another third because their buddy had run out of air.

Why practice emergency ascents ?

The main reason is training agency requirements. These are a hangover from the pre-contents gauge era, when to quote a SPUMS member at the Annual Meeting in Truk in 1977 "Every diver runs out of air once or twice a year !" Given such attitudes, there was a need to teach how to reach the surface safely when you ran out of air. The diving-related death statistics show that some failed to make the distance.

Skidding when driving can also be lethal, but no one has to practice on skid pans before getting a driving licence.

An argument in favour of emergency ascent training is that it demonstrates what the emergency feels like. This overlooks the panic factor. If an emergency ascent is really going to let the trainee find out what the out of air emergency is like it will be dangerous. No training agency can truthfully use this argument because it cannot allow such situations to arise. So the trainee does not learn what the emergency feels like but only what the training agency requires to be done.

Is emergency ascent training adequate ?

As far as I know no training agency makes trainees repeat the emergency ascent training the 17 to 21 times that are necessary to achieve competence in a complicated procedure such as buddy breathing.[4]

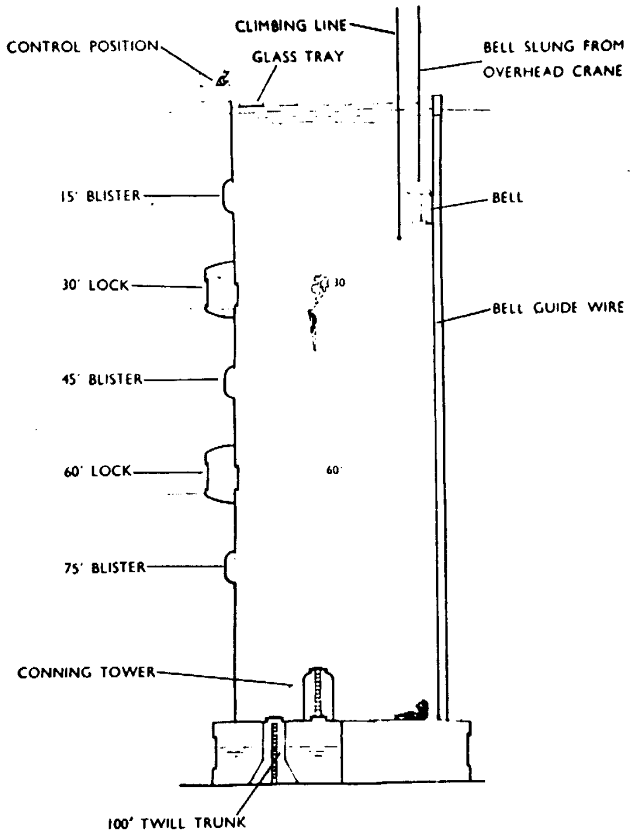
In December 1977 there was an Undersea Medical Society (UMS) workshop on Emergency Ascent Training.[5] The presentations were followed by discussions and all those engaged in training settled for continuing teaching emergency ascent, even though the figures then available showed that a small proportion of divers died during such training. A number of speakers mentioned that the number of training dives was inadequate, and that this was also true of teaching emergency ascent.

Douglas Walker reviewed the subject in 1990.[6] He showed that too many emergency ascents had ended in death. If the current training is ideal this should not happen. He quoted from Dr M.J.Nemiroff's comments reported during the UMS workshop discussion.[7] "One of the difficulties is that we are trying to train a skill for an emergency context that requires either a high degree of skill or extensive reinforcement or over-learning or all three. In a true emergency, where the mind is not working and the body is not functioning the way it should, the emergency technique that would be best would be one requiring absolutely zero skill, zero memory, and zero reinforcement."

Certainly no training agency is teaching such a technique.

FIGURE 1

DIAGRAM OF 30 M SUBMARINE ESCAPE TRAINING TOWER



Against practicing

With vertical ascents, such as specified by PADI,[8] the instructor is put through a number of ascents. This has lead to instructors requiring recompression.[9]

The navies of the world do emergency ascent training, reproducing the real thing, but with a recompression chamber and a medical team at the site.

The Royal Australian Navy now does its out of air ascents for divers at the closest possible point to the recompression chamber. Years ago they used the end of the wharf to get deeper water. This position was abandoned after a few accidents when the long carry (some 50 m) led to obvious deterioration in the diver's condition. Now the carry is much shorter but accidents still happen, especially when the procedure being practiced is complicated and has not been practiced for some years.

The incidence of fatalities in submarine escape training towers (SETT) is low thanks to the excellent supervision and medical facilities and the ability to get the diver under pressure in the chamber within seconds (Figure 1). The tower is 30 m deep. In the sides are alcoves (blisters) with the upper part glassed off to hold an air bubble. Instructors stand in these and swim out, breath holding, to be ready to help the trainee during the ascent. At the bottom is a compression chamber which contains a replica of the escape chamber installed in submarines. In the past this was a canvas trunking dropping into the compartment which had to be flooded to equalize the pressures so that the escape hatch could be opened. The first to escape held his breath, all submariners were male in those days, ducked under the skirt of the trunking and stood up. He undid the clips holding the hatch above his head and pushed it open. He was carried out with the air bubble and was on his way breathing out as he went. The second ducked into the

FIGURE 2

SETT BUOYANT ASCENT

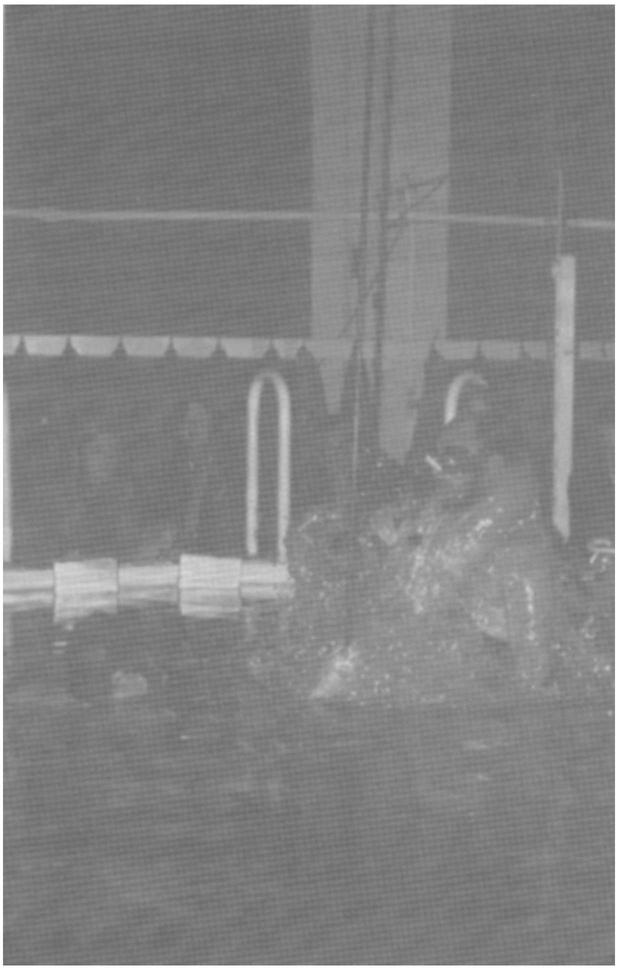


FIGURE 3

SETT ASCENT USING A BUCKET OVER THE HEAD

trunking and pulled himself through the hatch and pushed off breathing out. When this training was first introduced the trainees did a buoyant ascent, breathing out (Figure 2). Then someone realised that with ones head in an inverted bucket of air one can breathe during the buoyant ascent even if one cannot see (Figure 3). Hoods over the face were introduced and then survival suits (Figure 4).

In modern submarines the canvas trunking, which required flooding the submarine compartment and exposing the survivors to ambient pressure, has been replaced by a special chamber which the escaper steps into, shuts the door and plugs his hood and collar inflation tube into a compressed air supply. This action triggers very rapid pressurisation of the chamber and some filling of his hood and buoyancy collar. The hatch flies open and the escaper pops out. The hatch can be closed from inside the submarine, the door to the escape chamber opened and the water drains out. The system is then ready to use again. The risk of decompression illness (DCI) for the crew is much less than when using the old method as the submarine compartment stays at almost surface pressure. Using this equipment successful escapes have been made in the open sea from 180 m (600 ft). The doctors who recommended this system were among those who made these ascents.

The whole set up is geared for safety with instructors at the escape hatch who catch and clip the trainee to the wire and others available at various depths to help if necessary. In survival suits the trainees come up very fast indeed, hence the need to clip them to the wire to keep them from hitting the sides of the tank and damaging the paintwork. Figure 5, unfortunately taken without a flash, shows this trainee came out of the water at least to his knees. These people are breathing in and out all the way up. They have an air space in front of the face and so feel quite comfortable breathing. Since the introduction of this equipment in the early 1970s the incidence of accidents has gone down. But they still occur. The number of people put through submarine escape training towers is known and so is the number treated. The overall incident rate for these extremely fast ascents is approximately one in 2,500. In first time trainees it is probably as high as 1 in 1,900 ascents. This only gives a minimum number who have

FIGURE 4

SETT ASCENT WEARING A SURVIAL SUIT

FIGURE 5

SETT TRAINEE IN EXPOSURE SUIT BREAKING THE SURFACE

developed clinical DCI. Others have probably had less dramatic changes and escaped diagnosis.

The diagnosis of decompression illness, usually cerebral arterial gas embolism (CAGE), is simple. If the escapee goes unconscious he has DCI ! They stand near the recompression chamber (RCC) (Figure 6) at the top of the tower for a few minutes. If they fall, or say they are not feeling well, they are in the RCC within seconds and on their way to 50 m. Most wake during this compression and are then decompressed on the appropriate table. The problems are those who do not respond. But that is another story.

Reproducing an out of air situation by taking the regulator out of the trainee's mouth requires the trainee to breathe out all the way to the surface to avoid breath holding and the risk of cerebral arterial gas embolism (CAGE).

It has been known for over 35 years that breathing out can narrow and close small unsupported airways (bronchioles) trapping air, because they get squashed by the surrounding lung when the pressure within them drops below the general lung pressure.[10] This narrowing can happen to anyone who breathes out hard and such closure is common in the middle aged population. So breathing out may not avoid air trapping and this can lead to CAGE.

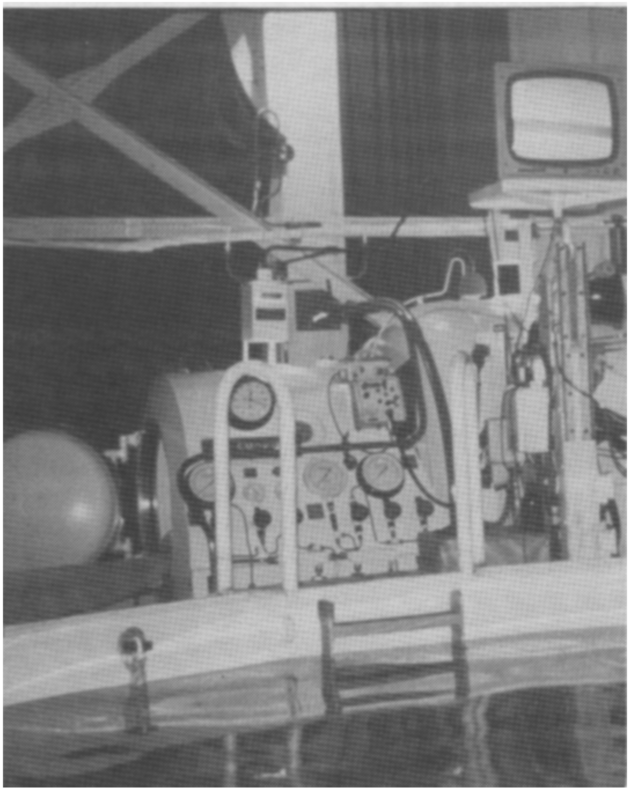
On the other hand not breathing out enough can leave the lung over-inflated, again predisposing to lung damage on ascent.

Either way the glottis must be open to allow air out of the lungs. Fright and panic often result in breath holding.

Breathing in and out during ascent, and even attempting to do this, prevents both of these problems. Attempting to breathe, even if no air is available, opens the small airways that have been closed by raised intrathoracic pressure.[10] This is because breathing in creates a negative intra-thoracic pressure. If one is attempting to breathe in and out on the way up it is likely that a breath or two or

FIGURE 6

RECOMPRESSION CHAMBER AT TOP LEVEL OF SETT



even more will come from the scuba cylinder as the depth decreases and the cylinder pressure rises above ambient. This will prevent hypoxia developing as the diver nears the surface.

Swimming ascents while not breathing can result, and have resulted, in the diver going unconscious from anoxia on the way to the surface. This is because swimming up when not buoyant is hard work. At functional reserve capacity (FRC), which is defined as the volume of air left in the chest at the end of a normal expiration and includes some air available to breathe out, the oxygen available at 30 m is 2,386 ml, 2,251 ml in the lungs and 137 ml in the blood (Figure 1, page 206).[11] Harpur and Suke calculated (Figure 2, page 207) that approximately 1,000 ml of oxygen would be vented from the lungs on the way up. By the time a diver, starting at FRC from 30 m, has swum up to 8.1 m below the surface he can be expected to have a PO of 40 mm Hg or less (Table 2, page 207). At this level people lose consciousness from hypoxia. If by chance he was still able to swim at 4.8 m below the surface he would have used all his available oxygen. Without buoyancy his chances of a breath of air can only be described as less than poor. If the diver had expired fully before running out of air the available oxygen would be lower and unconsciousness would come on deeper.

When these theoretical calculations were tested in a chamber, the pressure being reduced at a rate to be expected in a swimming ascent, they were confirmed. Because the "divers" were using equipment which allowed switching from ambient (chamber) air to a rebreathing bag for air sampling (Figure 3, page 208) they had a litre larger FRC and an equivalent increase in oxygen reserve than a diver in the water would have. The attendant terminated the exposure by opening the rebreathing valve to allow the subject to breath chamber air. Inspite of the larger oxygen store, at all starting depths below 13.5 m, every experiment had to be terminated while the chamber was still pressurised (Table 3, page 208). This was done whenever the diver could no longer pedal the ergometer steadily and maintain a regular tapping at the same time. In other words when they could no longer perform normally. Subject R (* on the table) went unconscious from hypoxia at 2.7 m before the attendant could move the valve to allow him to breathe chamber air. The depths of termination ranged from 1.2 to 3.6 m of seawater. This study showed the need for buoyancy to make certain that the diver reaches the surface when out of air.

Finally practicing emergency ascents encourages trainees to expect to run out of air.

What is needed for a safe emergency ascent ?

Firstly, a decision to start for the surface as soon as the problem starts (Table 1). Far too many deaths follow failed buddy breathing or octopus breathing. Usually the survivor is the one who bolts for the surface or drops the weight belt when disaster seems imminent.

Secondly, a procedure which will guarantee the diver reaching the surface. This requires that the diver becomes buoyant early in the ascent. The easiest way to achieve this is to discard the weight belt.

TABLE 1

FOR A SAFE EMERGENCY ASCENT

Head for the surface as soon as the problem starts

Use a procedure which will

guarantee the diver reaching the surface,

reduce the risk of hypoxia on the way up,

is easy to remember,

and has been practiced many times.

Thirdly, a procedure which will reduce the risk of hypoxia on the way up. This requires a source of air. Buddy breathing requires lots of practice to learn properly and must be practised regularly. Not many people practice it regularly enough, with the same buddy, to rely on buddy breathing. Octopus breathing requires less practice but it is very likely that the buddy is almost out of air. His first stage probably cannot supply both second stages at once. Hers, because most women use less air than men, may be able to do this. But almost certainly neither buddy's first stage will allow buoyancy compensator inflation while the buddies breathe.[12,13] Octopus breathing is probably a better source of air than buddy breathing but it is no certainty. A separate emergency air supply carried by the diver the safest option, provided the device contains enough air to get the diver to the surface. The simplest choice is to retain the regulator and try to breathe in and out. One will get a breath or two from the "empty" cylinder as the ambient pressure drops below cylinder pressure during the ascent.

And finally, a procedure which is easy to remember and has been practiced many times. Buddy breathing is not easy to remember under stress and is not often practised. The same applies to octopus breathing. Both require the divers to be close to each other to begin with and the divers have to hang on to each other. Although it is the best way of obtaining air in an emergency many divers will not carry a second air source because of cost. But all divers will practice having the regulator in the mouth and breathing in and out on every dive. They will practice taking the weight belt off and handing it into the boat, the same routine as for dropping it, on many occasions.

Is such a procedure possible ?

We believe that it is. It is the continuous breathing cycle ascent protocol.[14] We quote from Dr Harpur's paper (page 210).

1 Do not remove the regulator from your mouth unless you have another to replace it with, or in cases of entanglement. The regulator provides a safety valve and a possible source of air.

2 Continue to attempt to breathe in and out at all times even if out of air or without your regulator. This ensures an open glottis and larynx and minimizes the chance of small airway closure.

3 Make certain you become positively buoyant by inflating your buoyancy compensator or dropping the weight belt or both. This guarantees that you will reach the surface despite hypoxia.

The adoption of this protocol as advice to all divers wishing to dive at the Fathom Five Underwater Park at Tobermory in Ontario, Canada, led to a large reduction in the number of divers dying during out of air ascents. This was because they reached the surface and could be rescued. A side benefit was a reduction in decompression illness (CAGE) such that the chamber was very seldom used.[11] This advice reached all divers because they have to register with the Park authorities before being allowed to dive in the Park.

TABLE 2

TO ACHIEVE A SAFE EMERGENCY ASCENT

Waste no time in becoming buoyant

Keep the regulator in

Attempt to breathe in and out all the way up

Undo the weight belt and hold it away from the body

What needs to be taught ?

To achieve a safe emergency ascent the pupil must be taught (Table 2):

1 To waste no time in becoming buoyant once the decision to start for the surface is made. This requires constant repetition in the classroom, the pool and on every dive.

2 To keep the regulator in and attempt to breathe in and out all the way up. Never stop breathing when using compressed air underwater.

3 To undo the weight belt and hold it away from the body so that it will drop clear and not catch on the knife or other snags. If the diver goes unconscious the grip on the belt will loosen and the diver will drop it and become buoyant. This manoeuvre can be practiced on every dive either during the ascent or at the surface before handing the weight belt into the boat.

This is the diving equivalent of the driving school advice to "steer into the skid". All the diver has to remember is "Breathe in and out, become buoyant (take off the weight belt)".

Conclusions

Most emergency ascent training is useless because it is too complicated and not practised often enough to become automatic.

Some emergency ascent training is dangerous to pupil or instructor.

Too many out of air ascents fail to reach the surface.

There is a simple-to-learn routine (Table 2) which will see the diver to the surface, the continuous breathing cycle ascent protocol. This should become the standard teaching.

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Dr John Knight, FANZCA, Dip D and H M, is Editor of the SPUMS Joural. He has also served SPUMS as Secretary and President. He has been active in promoting diving safety since 1972.

His address is SPUMS Journal, C/o Australian and New Zealand College of Anaesthetists, Spring Street, Melbourne, Victoria 3000, Australia.

***The views expressed in this paper are Dr Knight's and not the policy of SPUMS**.*

Dr Guy Williams is a member of the SPUMS Executive Committee and presented this paper at the Workshop.

THE SPUMS WORKSHOP ON EMERGENCY ASCENT TRAINING

Des Gorman and Drew Richardson
Workshop Co-Chairmen

Introduction

The utility of emergency ascent training (EAT) has always been, and still is, controversial. Much debate on the efficacy and safety of EAT has preceded the SPUMS Workshop, but very little of it has been based on reliable, or even any, data. Such data-free subjective debates are unfortunately common in diving and diving medicine. Despite the reasonable consensus reached on EAT at the 1977 Workshop on this theme conducted by the (then) Undersea Medical Society,[1] the issue has been projected back into prominence by the development of a Code of Practice for diving in Queensland. Several SPUMS members and the Society itself have been consulted for an opinion. In the past, such a policy would have been produced by a volunteer or directed member of the Society's Executive Committee. Clearly, such policies may not reflect the overall opinion of the Society.

The SPUMS Workshop on EAT was designed to achieve the following two goals:

a to develop (if possible) a SPUMS policy on EAT; and,

b to illustrate that a Workshop is an appropriate method of forming Society policy.

In the final analysis, the Workshop achieved both goals admirably. Only on a single issue, buddy breathing ascents, was a consensus not possible. The widespread agreement was largely due to the "hard" data produced during the various presentations, which are published in this issue, and the active participation of those attending the conference. The Society's Guest, Professor David Elliott and his countryman, Phil Bryson, were particularly involved.

In addition to the invited presentations of Chris Acott, Drew Richardson, John Knight (given by Guy Williams) and Terry Cummins, written submissions were also received from James Francis (the Senior Medical Officer in Diving Medicine for the Royal Navy), John Williamson, Gerry Stokes (Irish Underwater Council) and Larry Williamson (Submersible Systems Inc.). All these