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CURRENT PHILOSOPHY AND PRACTICE OF EMERGENCY ASCENT TRAINING FOR RECREATIONAL DIVERS

Drew Richardson

The diving industry has worked hard over the past two decades to improve the safety of diving. The results have been more people diving safely. In comparison to other sports, diving has a low incidence of injury (Table 1). Relative to football, baseball, basketball, racquetball, tennis, swimming and bowling, recreational scuba diving has a lower injury rate.[1] Divers who dive within personal limitations, plan and follow proper diving practices, are generally able to avoid problem situations. Divers are encouraged to keep themselves fit, follow safe diving practices, and maintain diving skills.

The training organisations design course standards and materials to prepare trainees to dive safely with a buddy after certification. Skills thought to be crucial to producing a competent diver are therefore included. Occasionally problems do arise while diving. Divers do need to be able to care for themselves and lend assistance to another diver. Because of this, diving courses include components on problem management.

The process of training and education of divers aims to instil a safety attitude in the diver. If the diver is properly trained and has a safety conscious attitude, few problems actually occur while underwater and those that do can usually be prevented by using good judgment and common sense in and around the dive site.

Diver training organisations' course standards emphasise attention to a pre-dive safety check (buddy check), good dive planning, relaxing while diving, careful monitoring of ones air supply and diving within ones limitations.

The problem or running out of air is probably the easiest problem to avoid, yet is one of the most life threatening. Years of diving medicine emergency treatments inspired Dr Tom Neumann of University of California San Diego (USCD), to write, "Neumann's First Law of Diving," which states "a diver should never try to dive without air in his tank." To keep from running excessively low on, or out of, air divers are trained to make a habit of checking their submersible pressure (contents) gauges frequently. The submersible pressure gauge, one of the most beneficial

TABLE 1

INJURIES IN VARIOUS SPORTS

Sport	Number of Participants	Reported Injuries	Incidence
Football (US style)	14,700,000	319,157	2.17%
Baseball	15,400,000	321,806	2.09%
Basketball	26,200,000	486,920	1.86%
Soccer	11,200,000	101,946	0.91%
Volleyball	25,100,000	92,961	0.37%
Water Skiing	10,800,000	21,499	0.20%
Racquetball	8,200,000	13,795	0.17%
Tennis	18,800,000	22,507	0.12%
Swimming	70,500,000	65,757	0.09%
Bowling	40,800,000	17,351	0.04%
Scuba	2,600,000	1,044	0.04%

Participants are individuals who participate in the sport more than once a year. Injuries represent someone who was treated in an emergency room for an accident relating to a sport or involving sporting equipment.
Source: Accident Facts 1991 edition: National Safety Council (USA).

pieces of safety equipment, is a passive device that will only help a diver if the diver watches it, allows a margin of safety, and cares properly for the device.

Despite improved and comprehensive educational efforts to prevent an out-of-air situation from occurring, field reports indicate divers do run low on, or out of, air while scuba diving. Although one would think no trained, competent diver would consciously allow his air supply to run out while under water, annual statistics confirm that a few divers experience a loss or interruption of air supply underwater (sometimes with less than satisfactory results).

To support this point, an analysis of 125 incidents reported by Dr Chris Acott, indicated 18 out-of-air incidents.[2] Of these, 10 were resolved by using octopus breathing, three with buddy breathing, and 6 made a direct ascent. Furthermore, the 1991 Report on Diving Accident and Fatalities by the Divers Alert Network (DAN), states that air consumption was the probable starting cause in 11 of the deaths in 1991, including 10 drownings and one embolism.[3] Dr. Alise Curry's paper[4] indicates 3.9% of the treatments in the US Navy chamber at Guam were due to an out-of-air situation.

In the unlikely event that a divers air supply either runs out or stops unexpectedly, divers are trained to manage this problem by considering their options and acting intelligently. Three training agencies generally teach five options to be considered in low or out-of-air situation (Table 2).[5-7]

History of present policies on emergency ascent procedures

Before we look at current methods, it is useful to look at the evolution and history of modern techniques. In July 1976, a policy statement resulting from an agreement among training agencies was released by the North American based National Scuba Training Committee (NSTC).[8] The National Scuba Training Committee was the predecessor to the Recreational Scuba Training Council (RSTC). Its function and charter was to provide an opportunity for communication and cooperation between diving instructional agencies. Adoption of common polices and emergency procedures were one of the many tangible results. Participating agencies included NASDS, NAUI, PADI, SSI and YMCA.

In the mid 1970s the diving industry identified and recognised many problems which had been around since the 1960s. One such problem was that divers taught by different agencies might not react similarly in an emergency situation due to different training. It was conceivable two individuals, trained by separate agencies, diving together could compound the difficulty of an emergency situation by approaching it differently. The NSTC agreed to a consistent out-of-air emergency procedure policy to ensure that divers were trained to take the same action under similar circumstances.

As a result of this agreement, in April 1977, the NSTC released a policy on emergency ascent procedures. It identified and defined emergency options available to dives who experienced an apparent termination of air supply at depth. The committee first encouraged ***prevention*** of the situation as the best solution. The NSTC document presented many factors to be considered when dealing with which option to choose. The NSTC emphasised the importance of training divers to be capable of performing these skills. It did not specifically state how the training was to be conducted and left this to the discretion of the respective agency. The responsibility for training divers to select the most appropriate option for the situation was left to each agency. This policy statement formed the basis for the present procedures of NAUI, PADI, SSI and others. The NSTC broke the ground for co-operation between certification organisations for the exchange of ideas and philosophy.

Another landmark event that shaped the basis for modern day methods was the National Oceanic and Atmosphere Administration (NOAA) Sponsorship of the Fifteenth Undersea Medical Society Workshop on Emergency Ascent Training in Bethesda, Maryland, U.S.A. on December 10-11, 1977.[9] This workshop combined with the existing NSTC policy, became the starting point for the training protocols and controls used in today's emergency ascent training methods. The training models in place today reflect these recommendations. The PADI model includes a medical screen, logical skill development and progression, student skill preparation, reduction of student stress, maintaining the rate of training ascents at 18 m (60 ft) a minute or less, and pre-conditioning the student to know what to expect. Pre-conditioning involves the student reading about the procedure, learning about it in lectures, practising in the pool, being briefed and instructed on techniques, all before the procedure is performed in open water.

Defining emergency ascent

An emergency ascent is generally defined as any ascent performed by a diver as a result of any real or imagined emergency. In other words, any method of getting to the surface other than a normal ascent, regardless of the reason, method of propulsion or method of obtaining air (if any).

The agencies who formed the NSTC, and now the RSTC, define a number of procedures available to the diver in the event of an apparent termination of air at depth during a scuba dive. Ironically, this is training for something that should not happen. It must be emphasised that

TABLE 2

COMPARISON OF EMERGENCY ASCENT TRAINING ENTRY LEVEL SCUBA COURSE CONTENT (BY AGENCY)

	Academic Informatin	Confined Water Skills Training	Open Water Skills Training	Depth Restriction
NAUI				
Emergency swimming ascent	Yes	Yes	Yes Vertical with line required	9 m (30 ft) or less
Buddy breathing ascent	Yes	Yes Stationary, swimming, horizontal and vertical	No ascent Skill practiced stationary	9 m (30 ft) or less
Positive buoyant ascent	Yes	Yes Vertical	No	9 m (30 ft) or less
Octopus assisted ascent	Yes	Yes Stationary and swimming	Yes Vertical	9 m (30 ft) or less
Normal ascent	Yes	Yes	Yes Vertical	18 m (60 ft) max
PADI				
Controlled emergency swimming ascent	Yes	Yes Horizontal	Yes Vertical with line required	9 m (30 ft) or less
Buddy breathing ascent	Yes	Yes Stationary, swimming, horizontal and vertical	Yes Stationary and vertical	9 m (30 ft) or less
Positive buoyant ascent	Yes	No	No	-
Octopus assisted ascent	Yes	Yes Vertical	Yes Stationary and vertical	-
Normal ascent	Yes	Yes	Yes	18 m (60 ft) max
SSI				
Emergency swimming	Yes ascent	No	No	-
Buddy breathing ascent	Yes	Buddy breathing stationary	No	-
Emergency buoyant ascent	Yes	Yes Vertical, no line	Yes Vertical with no line required	12 m (40 ft) or less
Octopus assisted ascent	Yes	Yes Stationary and vertical	Yes Stationary and vertical	12 m (40 ft) or less
Normal ascent	Yes	Yes	Yes	18 m (60 ft) max

Sources:
PADI Instructor Manual, 1251 East Dyer Road, Santa Ana, California 92705, @ February 1990.
NAUI Instructor Manual, P.O. Box 14650, Montclair, California 91763, @ March 1984,
SSI Instructor Manual, Concept Systems Inc., 2619 Canton Court, Fort Collins, Colorado, 80525, @ January 1987.

all organisations and instructors strongly advocate careful air management and avoidance of out-of-air problems to student divers.

Selection of an acceptable course of action is dependent on many variables, including depth, visibility, distance from the buddy, nature of the activity, where the attention of others is focussed, the diver's breath holding ability, the training level of the divers involved, the stress levels and experience of each diver, obstructions on the way to the surface, water movement, the diver's buoyancy, familiarity with skills, equipment similarities between divers, the apparent reason for the air loss, and decompression requirements. Scuba instructors educate students about the variables to be considered and their relation to the selection of an appropriate emergency procedure.

Diver training philosophy for each agency now incorporates a common base line so that individual divers should make similar decisions under the same set of circumstances and to simplify training. These points are important as the actual circumstances are complicated by stress.

Therefore training is conducted with the objective of providing divers with a safe and effective emergency procedure for an out-of-air situation when they are no longer under the supervision of an instructor. Divers are taught to co-ordinate as a buddy team before going into the water for any scuba dive, and to review the emergency procedures to be used if either diver runs out-of-air at depth. The use of a buddy system, including a pre-dive safety drill, requires buddies to inspect each other's equipment and establish protocols for the dive.

Defining Options

Emergency ascents to the surface (which generally are the result of a low air situation) may be handled in several ways depending on the circumstances of the incident. Whenever possible, a direct swimming ascent, with the mouth-piece in place, is desirable. This usually will allow the diver to draw additional air from a seemingly empty tank as the water pressure decreases. The diver who is neutrally buoyant will find this ascent easy because air in the buoyancy control device (BCD) will expand as the diver rises.

The training organisations have established several possible courses of action for an out-of-air situation. The first step in evaluating an out-of-air situation should be to confirm the existence and nature of the apparent air loss. In low on air or out-of-air situations, divers are trained to stop, think and consciously attempt to breathe and if successful in doing so, proceed with a normal ascent. Normal ascents are repetitively trained throughout the course of all entry level scuba courses.

FIGURE 1

FLOW CHART FOR OUT-OF-AIR EMERGENCIES

Based on NSTC policy on emergency ascent procedures
April 1977

Emergency

Apparent termination of air supply

Confirmation
Normal ascent if possible

Dependent action	Independent action
preferred	**preferred**
Use of octopus	Controlled emergency swimming ascent
second choice	**second choice**
Buddy breathing	Buoyant emergency ascent

Students are made aware that most out-of-air situations are caused by human error. Often human factors can be corrected if they are considered before resorting to emergency procedures. Emergency procedures for divers in out-of-air situations can be categorised as either dependent or independent (Figure 1).

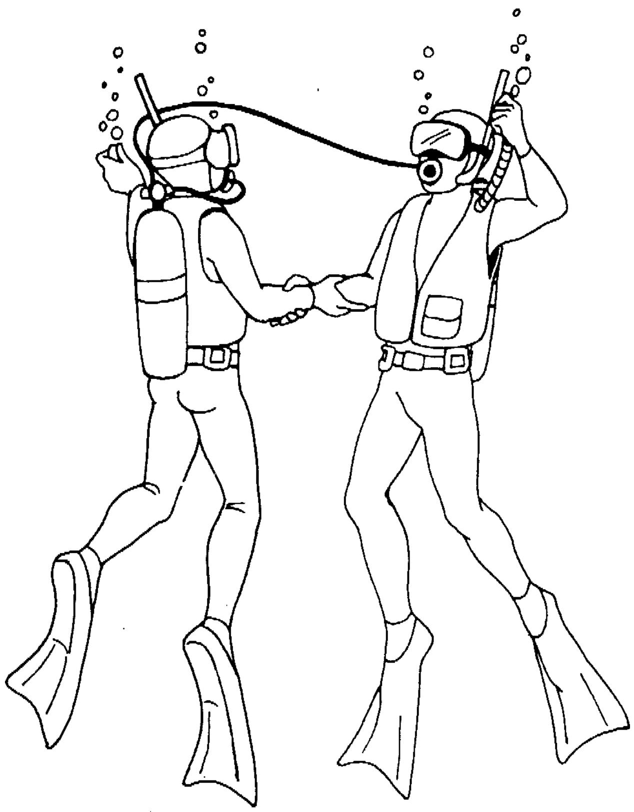
Dependent options

Dependent options are defined as those occasions when the emergency ascent requires the assistance of another diver. In this category the most desirable option, is the use of an alternative air source, usually an additional second stage (Figure 2). The octopus permits both divers, each with their own mouthpiece, to breath from a single first stage during the ascent. Students are encouraged to include this extra second stage as part of their normal equipment. In 1986 the alternative air source became an industry standard, for entry level open water training, as part of the American National Standards Institute standard. Alternative air source breathing is a component of entry level course standards for NAUI, PADI and SSI.[5-7]

Buddy breathing is another dependent option. Here two or more divers share a common air supply by passing the regulator second stage from one diver to another (Figure 3). This is a less desirable option because of it is a complex manoeuvre and there is much evidence of its breaking down under stress. Buddy breathing protocols first establish a stationary breathing cycle and which is then continued during the ascent to the surface. Buddy breathing techniques are taught as a component of entry level course standards for NAUI, PADI and SSI.[5-7]

FIGURE 2

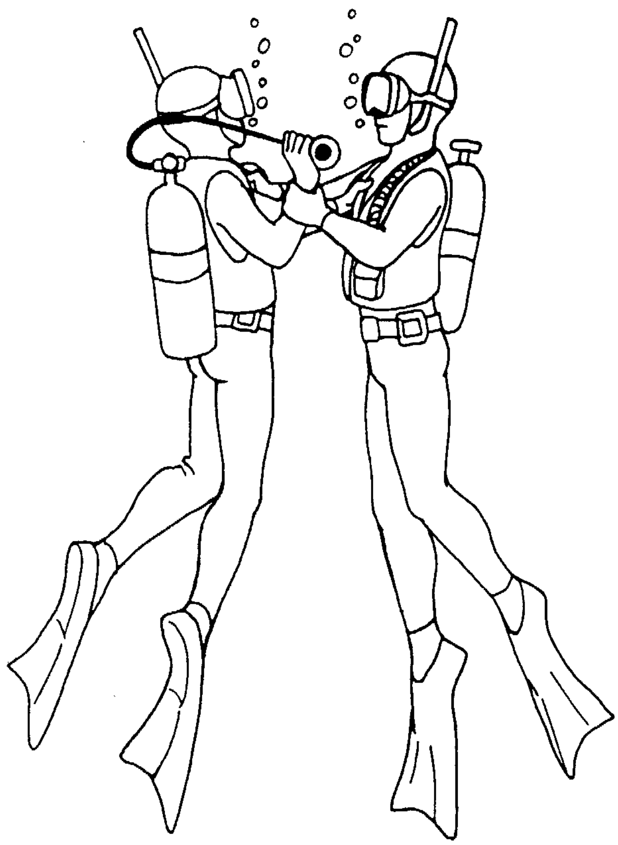
ALTERNATIVE AIR SOURCE



Source NAUI Openwater 1 Scuba Diver Instructor Guide 1987

FIGURE 3

BUDDY BREATHING



Source NAUI Openwater 1 Scuba Diver Instructor Guide 1987

Independent options

An individual may be away from the buddy or unable to gain the buddy's attention. This situation requires an independent ascent. If a diver has an independent air supply such as Spare Air or a pony bottle, as well as his failed primary supply, this would generally be the recommended choice. Otherwise a controlled emergency swimming ascent is recommended as the primary independent emergency option. The diver swims to the surface with the regulator in the mouth, exhaling continuously (Figure 4). The controlled emergency swimming ascent is taught as a component of entry level course standards for NAUI, PADI and SSI.[5-7]

The buoyant emergency ascents is felt to be a final option when no other options are recommended or available. Here the diver drops his or her weights and utilises lift from all forms of buoyancy, BCD and exposure suit (Figure 5). A buoyant ascent should be used when the diver has doubts whether the surface can be reached by swimming. This method of ascent is taught as theory by NAUI, PADI and SSI, in confined water by NAUI and SSI and in open water by SSI.[5-7]

Divers are trained by instructors of RSTC agencies to select an appropriate course of action for the circumstances.

Procedures

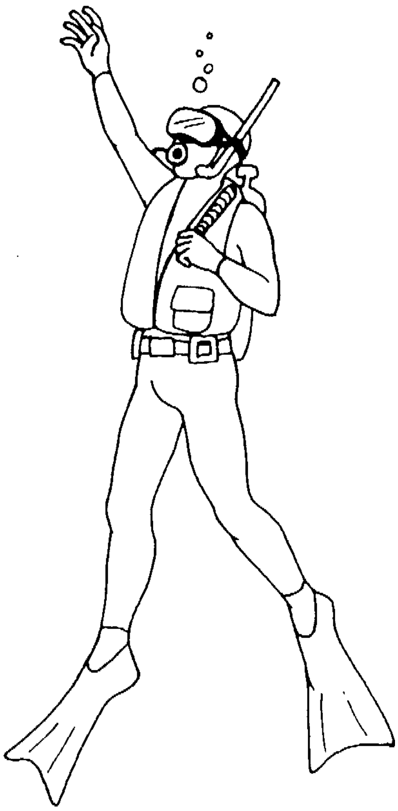
Emergency ascent training methods have been improved and refined over the course of time. The manner and the conditions in which training is conducted are important. Before engaging in this training students are preconditioned to reduce stress. Unfavourable environmental conditions are avoided when the instructor chooses an open water site. The instructor stays in contact with the student and is in control. Several improvements have been made over the years in the design of educational training materials and methods to conduct realistic, yet safe training. Let us look at a few key points in conducting this training.

NORMAL ASCENTS

In handling low-on-air situations, divers are taught to make a normal ascent. If a diver's tank is not completely empty a diver can often make a normal ascent. As the

FIGURE 4

CONTROLLED EMERGENCY SWIMMING ASCENT



Source NAUI Openwater 1 Scuba Diver Instructor Guide 1987

FIGURE 5

BUOYANT EMERGENCY ASCENT

Source NAUI Openwater 1 Scuba Diver Instructor Guide 1987

diver ascends, the water pressure surrounding the diver decreases allowing more air to flow from the tank.

ALTERNATIVE AIR SOURCE ASSISTED ASCENT

The use of an alternative air source, either an additional second stage from a buddy or ones own pony bottle, is probably the easiest way to solve an out-of-air problem and is generally thought to be the best all around choice. Divers are taught to locate, secure and use an alternative air source from a buddy diver. During buddy checks and predive safety drills, divers are asked to look for the alternative air source.

During training, students practice alternative air source use, both when stationary and swimming, in confined water before ascent work. Alternative air source stationary skill practice proceeds any ascent training in open water. All ascents are conducted at a rate not to exceed 18 m (60 ft) per minute. Divers should establish physical contact with an arm link up and maintain buoyancy with the other hand on the inflator hose as they swim to the surface (Figure 3).

CONTROLLED EMERGENCY SWIMMING ASCENT

Divers who have no alternative air source or whose buddy is too far away to provide one, may decide to make a controlled emergency swimming ascent. This differs from the technique knows as free ascent. A free ascent is defined as an ascent made without any air supply, during which the diver exhales all the way to the surface. The United States Navy requires that the lung volume be maintained at the “near full” capacity (high into inspiratory reserve) in order to add buoyancy and only the excess expanding air is exhaled.

A controlled emergency swimming ascent requires that the lung volume be kept in the mid-tidal volume range and no extra buoyancy is gained from the pulmonary air. A controlled emergency swimming ascent involves swimming to the surface, exhaling continuously through the second stage, making an “ah” sound into the regulator to release expanding air and prevent lung over-expansion injury. The driving force of the ascent is provided by kicking the fins.

During training, if the student misjudges the amount of air exhaled, they simply take a breath from the regulator, which is in the mouth, and the exercise is repeated. Controlled emergency swimming ascent is not a difficult exercise and divers are taught it first horizontally in confined water and then vertically in open water under the control of an instructor. Several agencies require the instructor to maintain strict physical contact with the student and a fixed line to arrest the ascent at anytime. Ascents are conducted from a maximum depth of 9 m (30 ft) or less (Figure 4).

BUDDY BREATHING WITH A SINGLE REGULATOR

If divers are in a situation where depth or physical characteristics complicate ascent and there are not other alternative air sources available, they may need to share air by buddy breathing, passing one regulator back and forth between themselves. The donor controls the air source by maintaining a hand on the mouth piece while the receiver's hand is placed near the rescuer's. In this way, either diver may guide the regulator into their own mouth. The purge button is generally left uncovered so that either diver may reach it. At not time should the donor allow the receiver to control the air source. Buddies sharing air must avoid separation due to changing buoyancy during the ascent. This is done by holding onto one another. Divers need to exhale while rising when the regulator is out of the mouth, and are taught to always blow bubbles between breaths.

As emergency buddy breathing is done to reach the surface, divers will normally face each other. If it is necessary to swim horizontally to get clear of an overhead obstruction, the divers can swim side by side. Buddy breathing is thought to be a difficult method of emergency ascent. In most cases a controlled emergency swimming ascent or an alternative air source ascent will provide a safer, more effective means of reaching the surface. Although buddy breathing is more difficult than using an alternative air source, it can be managed if the buddy team remains calm and is familiar with the procedure. Once buddy breathing is initiated, the team should continue all the way to the surface without attempting to switch to another out-of-air option.

This technique is not taught by all agencies. Those that do teach it, develop the skills, both stationary and swimming, in confined water before any open water ascent training. With the advent of the alternative air source, buddy breathing training is diminishing. However certain areas of the world still do not have widespread use of an alternative air source.

BUOYANT EMERGENCY ASCENT

Another out-of-air option is the buoyant emergency ascent. This requires dropping the weights and inflating the BCD, exhaling continuously making the "ah" sound as the diver rises to the surface. This option should only be used when the buddy cannot be located and there is no alternative air source available and the diver doubts that he can reach the surface by an controlled emergency swimming ascent. In a buoyant ascent a diver is lifted toward the surface by his buoyancy. This positive buoyancy is combined with swimming efforts. Of NAUI, PADI and SSI only one organisation conducts this skill in open water, two have skill sessions in confined water, and one only covers this skill in an academic context with no motor skill training.

BUDDY TEAMWORK

Divers are encouraged to discuss out-of-air emergency options with their buddy before the dive and to stay close together, so that they may assist each other if necessary, especially as they go deeper. An alternative air source is a standard part of equipment training for NAUI, PADI and SSI and a growing standard of practice. Buddy teams looking after one another, watching air supplies, breathing patterns, time and depth limits, remaining alert and monitoring each other generally are the best way to avoid any air supply problems.

Summary

Preventing situations necessitating an emergency ascent is the best course of action. Running out of air is probably the easiest problem to avoid. To keep from running excessively low on or out of air, divers need to check their gauges frequently. In the unlikely event that a diver runs out of air trainees are taught to consider their options and act intelligently along the dependent or independent pathways described. The techniques are meant to be simple and easy to remember without practice and we attempt to train divers to not risk another person.

It is impossible to measure the number of times divers have utilised one of these techniques, after training, to manage an out-of-air situation successfully and avoid injury. The improving safety record with an ever increasing diving population, suggests that emergency ascent training is useful. It is known that over the years these techniques have saved lives. It is also known that a number of divers using these techniques did not do so successfully and failed to reach the surface.

Careful monitoring of air supplies and attention to depth and time limits will prevent out-of-air problems. Divers are taught to start back for the exit point with a more than adequate air supply remaining. They are taught to begin ascents with more than an adequate supply for coping with emergencies or delays on the way up. Divers are taught that breathing a tank dry is a bad habit and that no one condones this practice. It is a habit that has repeatedly cost lives.

There is no ideal emergency ascent method that is universally applicable. The variables of each emergency dictate the best course of action. Often these variables in a time of stress override the ability of the diver. Because of this, the agencies teach an order of preference and simplicity. Based on diving accidents, the buddy breathing ascent has been shown to be a difficult procedure to perform in times of stress. It is generally agreed that a diver may swim immediately to the surface during an emergency, from a shallow depth, so avoiding the crucial time delay that assisted ascents entail. Alternative air source ascents are usually simple and easy to perform. Their disadvantage lies in needing an alternative air source on the diver or on the donor's equipment.

The training organisations feel that emergency ascent training is a necessary and valued skill in the training of new divers.

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OUT-OF-AIR ASCENTS FROM THE DIVING INCIDENT MONITORING STUDY

Chris Acott

Introduction

This paper presents the Diving Incident Monitoring Study data available up until the end of 1992 on the out-of-air/low air problems. It is an analysis the safety of the various emergency procedures designed to cope with this situation. These emergency procedures can be placed in one of three groups.

1 An ascent to the surface, exhaling all the way. Some call this a free ascent. In this paper it is called a non-breathing ascent. This technique includes an emergency swimming ascent.[1,2]

2 The sharing of a buddy's regulator, either a spare second stage (octopus breathing) or the buddy's second stage (buddy breathing).[1,2]

3. The use of a totally separate air supply from a spare cylinder (i.e. a pony bottle or SPARE AIR).[1,2] None of the ascents considered here was in this group.

An out-of-air situation is not an uncommon event in diving. 82 (15%) of the 533 incidents reported have involved an out of air problem. 21 (26%) of these incidents involved morbidity (Table l) and this represented 8% of all the harmful incidents reported.

There were 49 low air incidents, and 19 (40%) of these became an out-of-air problem. Of the remaining 30 low air incidents 9 (33%) resulted in harm, (seven incidents of decompression sickness, one of cerebral arterial gas embolism and one of salt water aspiration). These harmful low air incidents were associated with omission of decompression stops, poor dive planning, poor air maintenance and various problems developing at a "Safety Stop" resulting in a rapid ascent to the surface.[3] The addition of another incident (ie the loss of a fin or the retrieval of an anchor at the end of a dive) were the main causes of a low air problem becoming an out-of-air situation.

TABLE 1

HARMFUL INCIDENTS FOLLOWING OUT-OF-AIR ASCENTS

Sequelae	Incidents
Decompression sickness	9
Cerebral arterial gas embolism (CAGE)	3
Pulmonary barotrauma and CAGE	1
Pulmonary barotrauma	2
Salt water aspiration	4
Salt water aspiration and complications	1
Near drowning	1
Total	**21**

Experience

An out-of-air problem is not confined to the inexperienced as 71% of the divers running out of air had better than basic qualifications (Table 2). However novice divers have a greater chance of injury. Students, basic and open water divers accounted for all the incidents of cerebral arterial gas embolism, pulmonary barotrauma, salt water aspiration, near drowning and two incidents of decompression illness. There were 14 harmful incidents in 43 novices, an incidence of approximately 33% while the more experienced divers had 7 harmful incidents in 39 ascents (18%).

TABLE 2

QUALIFICATIONS

Certification	Number	%
Basic	18	22
Open Water	25	31
Advanced	12	15
Dive master	4	5
Dive instructor	11	13
Commercial	6	7
Not recorded	6	7
Total	**82**	**100**