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EMERGENCY ASCENT TRAINING WORKSHOP

10-11 December 1977

Co-Chairmen

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Editor
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The Fifteenth Undersea Medical Society Workshop

Undersea Medical Society, Inc.
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Bethesda, Maryland 20014

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CONTENTS

Section I. Workshop Report

Section II. Individual Papers

Section III. Additional Papers

Sponsor's Statement

The National Oceanic and Atmospheric Administration, in cooperation with the Undersea Medical Society, is very pleased to be able to support this important workshop on emergency ascent training. The undercurrent of controversy regarding training in emergency ascents has been growing steadily. There is general agreement that such training, despite its obvious risks, is essential to the development of properly trained divers. However, recent actions and decisions of insurance companies have served to further accentuate the problem of this instruction. NOAA hopes that this workshop will produce a report which takes a step beyond the April 1977 policy statement of the National SCUBA Training Committee and will resolve this controversial issue to everyone's satisfaction.

Many concerned groups and viewpoints are represented by the cross-section of experts in attendance at this workshop. The selection committee believes that it has brought together a careful balance of viewpoints which will allow informed discussion and debate on all aspects of emergency ascent training. It is essential to the success of this workshop that personal bias give way to careful consideration of all the facts to be aired here. The diving community needs an answer to this question and a consensus response by this workshop will provide that answer in a timely manner. NOAA and the UMS are confident that you will produce a satisfactory position regarding emergency ascent training that we all can live with.

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American Sport Diving Schools, Inc.

Florida Institute of Technology

National Association of Scuba Diving Schools

National Association of Underwater Instructors

National Oceanic and Atmospheric Administration

Naval School of Diving and Salvage

Professional Association of Diving Instructors

Professional Diving Instructor College

Scripps Institution of Oceanography

Scuba Schools International

Young Men's Christian Association

THE NATIONAL SCUBA TRAINING COMMITTEE ASCENT TRAINING AGREEMENT

In April 1977, five major American diver training organizations formally adopted a policy on training in emergency ascent procedures. This policy statement, made under the aegis of the National Scuba Training Committee (NSTC), was adopted by the following organizations: National Association of Scuba Diving Schools (NASDS), National Association of Underwater Instructors (NAUI), Professional Association of Diving Instructors (PADI), Scuba Schools International (SSI), and the Young Men's Christian Association (YMCA), in response to the recognized need for divers to be trained in common emergency ascent procedures. The NSTC agreement is reproduced below, to provide a frame of reference for readers of this Workshop report.

Evaluating the Situation

These agencies recognize a number of procedures are available to the diver in the event of an abrupt, apparent termination of air at depth during a scuba dive. Selection of an acceptable course of action is dependent on many variables, including: depth, visibility, distance from others, nature of activity (i.e., swimming versus stationary, photography versus spearfishing, etc.), focus of attention of others, available breath-hold time, training level of divers involved, recency of training, stress level of each diver, experience of divers involved, obstructions to the surface, water movement, buoyancy of the divers, equipment, familiarization of skills and equipment between divers, apparent reason for air loss, and decompression requirements.

Scuba instructors are to make students aware of the variables to be considered and their relation to the selection of an appropriate emergency procedure. Diver training should be conducted so divers trained by different instructors would make the same decision under a specific set of circumstances. Training should be conducted with the objective of providing divers with safe and effective emergency procedures for an out-of-air situation, when they are no longer under the supervision of the instructor. Divers should be taught to coordinate, prior to entering the water for any scuba dive, emergency procedures to be used for an abrupt air termination at depth.

Possible Courses of Action

The first step in evaluating an out-of-air situation should be the confirmation of the existence and nature of the apparent air loss. Before selecting a more radical or risky option, the diver should stop, think consciously, attempt to breathe, and, if successful in doing so, proceed with a normal ascent. Students should be made aware that many out-of-air situations lie with the diver and/or the situation rather than in equipment malfunction or actual depletion of the air supply. These human factors often can be corrected if first considered before resorting to emergency procedures.

Courses of action to be recommended to a diver in an out-of-air situation may be categorized as either dependent or independent. The most desirable option in the dependent category involves the use of an additional second stage (Octopus) which permits both divers to breathe with their own second stage during the ascent. Students should be encouraged to include this extra second stage regulator as part of their equipment.

Buddy breathing by regulator exchange under emergency conditions is the other dependent option and is the least desirable of the dependent options. Once a satisfactory breathing cycle has been established, buddy breathing should be continued with a reasonable rate of ascent to the surface.

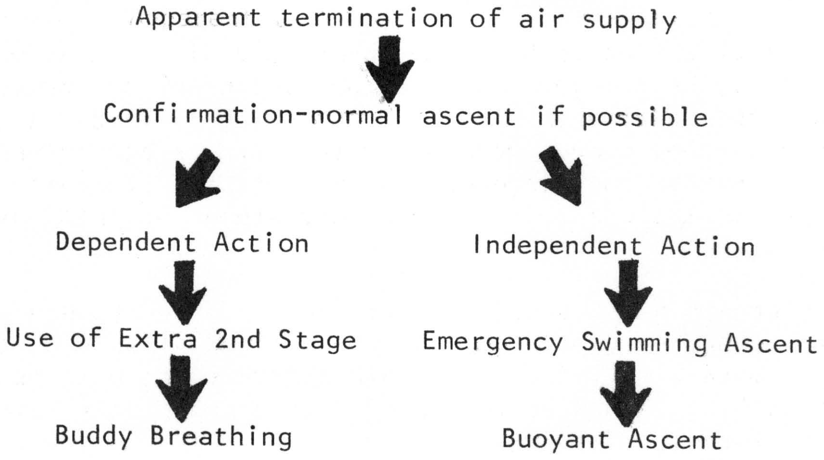
An emergency swimming ascent, recommended as the primary independent emergency option, is accomplished by the diver swimming to the surface while exhaling continuously.

Another course of action is buddy breathing followed by an emergency swimming ascent. If this procedure is used, it should be initiated on the bottom, where buddy breathing is used to regain composure prior to the swimming ascent, and not resorted to during a buddy breathing ascent. Whenever divers ascend while sharing air, they should continue to share air until surfacing.

The final option, and no other options are recommended, is a buoyant ascent. This is an ascent made by dropping weights, or by using some other form of buoyancy such as an inflated buoyancy compensator. A buoyant ascent is used when a diver seriously doubts the surface can be reached by swimming.

Divers are trained by the instructors of the participating agencies in the possible courses of action, selection of an appropriate course of action for various circumstances, and in performing the various courses of action. Some restraints in the training of certain emergency procedures are in effect by agencies adopting this policy. Specific training methods are established by the individual agencies. Questions regarding the emergency procedures, training requirements and methods of a particular agency should be directed to that agency.

EMERGENCY!


Apparent termination of air supply
Confirmation-normal ascent if possible
Dependent Action
Independent Action
Use of Extra 2nd Stage
Emergency Swimming Ascent
Buddy Breathing
Buoyant Ascent

SECTION I

WORKSHOP REPORT

INTRODUCTION

Few aspects of diver training have been more controversial than the teaching of emergency ascent procedures. The controversy centers on techniques, psychological and physiological considerations, concern about today's legal climate, and, finally, the moral issue: is it wise and ethical to train divers in emergency ascent techniques, even though this training may itself be hazardous? Finding a solution to this controversy becomes more important as the number of divers involved in sport and recreational diving increases.

The issue has been warmly debated in the diving instruction and medical literature, but no resolution had been achieved at the time this workshop was held. The workshop therefore brought together representatives of the major U.S. diver training organizations, leading figures in the field of diving medicine, and officials of the Federal agencies involved, in the hope that a satisfactory consensus could be achieved. The report and discussion that follow reflect these concerns.*

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*Most of the discussion that follows has been paraphrased from transcriptions of the workshop, without attribution to specific speakers; in some cases, however, particularly when a written statement was presented, remarks are attributed to specific speakers.

DISCUSSION

The attention of workshop participants was first directed to defining the problem and choosing the proper terminology. The group agreed that the term free ascent should be used only in connection with U.S. Navy submarine escape training.* Also, it was pointed out that stress was a primary feature distinguishing an emergency from a normal ascent: the chief difficulty in any ascent is maintaining a safe pressure gradient. The consensus was that the most descriptive and accurate term was emergency ascent.

This term covers at least seven different procedures:

1. exhaling ascent
2. emergency swimming ascent
3. (shared air) buddy breathing ascent (one regulator)
4. (shared air) buddy breathing ascent (octopus)
5. reserve air ascent (pony or bailout bottle)
6. buoyant ascent initiated by weight belt drop
7. buoyant ascent using a flotation device

(In practice, few emergency ascents are "pure"; stress usually causes the diver to use several techniques in the same ascent.)

These ascent procedures can be grouped into two categories: those requiring dependent action (intervention by another person or persons) and independent action (initiated and conducted solely by the involved diver).

Buoyant ascents, emergency swimming ascents, and ascents using a reserve air supply are independent ascents (unless the reserve is supplied by another diver); buddy breathing ascents, whether from one regulator or an octopus rig, are dependent ascents.

Representatives from the training agencies agreed that all divers should be taught these ascent techniques, and all the teaching institutions do, in fact, teach at least one of these techniques, either in lecture, pool, or open water. Two of the training agencies include buoyant ascent in their curricula, and three emphasize swimming ascent. All of the training organizations teach exhaling, swimming, and buoyant ascent techniques, but not all agencies teach these procedures in the open-water situation.

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*Readers will note that this resolve was honored more in the breach than in the observance in the course of this workshop.

SIGNIFICANCE OF THE PROBLEM

In preparation for this workshop, data collected by the National Underwater Accident Data Center, University of Rhode Island, were analyzed for the seven-year period 1970-1976 (Table 1). Of the 80 recorded fatalities in this period that occurred in training programs conducted by recognized national certifying agencies, 28, or 25% of the total, happened during emergency ascent training. The total number of emergency ascent training exposures during this interval is estimated to have been over 2½ million, for a mortality incidence of roughly 8 in one million exposures (.00000779).

Table 1. Fatal accidents and fatality rates during emergency ascent training, 1970-1976

Type of Ascent	No. Ascents	No. Fatalities	Fatalities/ Total No. Ascents
Swimming (exhaling)	640,000	9	0.0000141
Buddy breathing	1,305,000	10	0.0000077
Octopus-pony bottle	60,000	1	0.0000167
Buoyant	560,000	8	0.0000147
Total	2,565,000	28	0.0000109

Data derived from University of Rhode Island National Underwater Accident Data Center.

Table 2 shows the breakdown, by agency and type of training, of the data for these years.

Table 2. Emergency ascent training exposures

Training Agency	Type of Ascent	No. of Exposures
YMCA	Buddy	160,000
	Octopus	10,000
	Exhaling	50,000
	Buoyant	--
SSI	Buddy	120,000
	Octopus	5,000
	Exhaling	--
	Buoyant	60,000
NASDA	Buddy	250,000
	Octopus	40,000
	Exhaling	--
	Buoyant	300,000
NAUI	Buddy	490,000
	Octopus	--
	Exhaling	490,000
	Buoyant	--
Scripps	Buddy	10,000
	Octopus	10,000
	Exhaling	10,000
	Buoyant	1,000
PADI	Buddy	295,000
	Octopus	10,000
	Exhaling	100,000
	Buoyant	200,000

Half of the total number of deaths occurred during training in the technique of buddy breathing (shared regulator), nine during exhaling swimming ascent training, and one fatality happened when two divers were practicing the octopus procedure. Buoyant ascent techniques were not separately analyzed statistically. Some of the deaths attributed to buddy breathing probably occurred when one partner panicked, abandoned the shared air technique, and attempted an emergency swimming ascent.

Although these data indicate that the problem is statistically insignificant (though not so in human terms), morbidity data, the number of near-misses subsequently treated, and the number of incidents that were without symptoms and therefore went unreported, are not included in these statistical summaries. Although the data are incomplete, the number of fatalities associated with training is accurate, and all participants agreed that the estimate of the number of training exposures was conservative.*

U.S. Navy Submarine Escape Training Data

The best data available for a large group of men derive from the U.S. Navy's Submarine Escape Training Tanks, but these data should not be compared statistically with sport diver training data because the Navy environment is so different: Navy trainees are in 100 feet of water in a 135-foot high cylindrical tank; they are carefully selected for submarine duty; they are watched continuously; and they have immediate access to a recompression facility and to medical care -- on the other hand, however, Navy trainees have had no diving experience, and some cannot even swim.

The Navy practiced four types of ascents during the period for which data are reported in Table 3: submarine escape apparatus (SEA); free; buoyant; and Steinke hood (a semi-rigid air- or oxygen-filled hood covering the head and resting on the shoulders of the trainee). For the period 1930-1965, there were only four deaths in over 373,000 simulated escapes (0.0000106).

Table 3. Morbidity and mortality in simulated escapes, and modes of escape, U.S. Naval Submarine Escape Training Tank, New London, 1938-1963 (C.L.Waite et al.,Cerebral air embolism,1967)

Years	Mode	No. Escapes	No. Air Embolism Cases (Morbidity)	No. Deaths (Mortality)
1930-1953	S.E.A. Momsen Lung	193,000	7 .0000362	1 .0000051
1942-1957	Free Ascent	17,583	15 .000853	2 .0001137
1957-1965	Buoyant Ascent	130,679	12 .0000918	1 .0000076
1963-1965	Steinke Hood	32,679	5 .000153	0 .0000000
Total		373,941	0.0001042	0.0000106

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*These figures also do not include data from "ditch and don" training exercises, which are conducted by most certifying agencies.

Having considered and evaluated what morbidity-mortality data exist on emergency ascent training, the workshop participants turned to a discussion of the moral issue, physiological problems, and procedural questions associated with training in emergency ascent.

THE MORAL ISSUE - CONCLUSION

Most participants agreed that the data clearly did not indicate that training agencies should stop training divers in emergency ascent techniques, but there is an obvious need to improve these training techniques. The following paragraphs report the general nature of the discussion that took place.

Dr. Lanphier: The statement I came with is fairly passe, but there are a few passages that I think might be worth considering. We will, among other things, be trying to decide whether or not it is all right to kill or injure a certain number of people to save a very uncertain number of others who might otherwise die or be injured in actual diving. In fact, I do not feel very confident that ascent training in the open water adds a great deal to what we could accomplish with optimal classroom and pool training, although there are no numbers available on that subject. This training should be a thoroughly voluntary procedure on the part of trainees; it should not be required for certification by any group, and there should be no special pressure or other form of coercion applied to people to take this kind of training.

Mr. Hardy (speaking for the five training agencies): Before we go too far, the members of NSTC met yesterday. We have some very strong moral convictions about the people we are training. If we did not have these convictions, if it was only a legal issue, we would not be here; we would settle it with our attornies and our insurance companies. We are morally concerned about losing anyone during training. We are losing a certain number through ascent training and also losing others due to other problems in training. We could entirely eliminate our legal liabilities by getting out of open water training entirely. Morally, however, we cannot live with than, because we have lost a total of 80 people, 20 of them during ascent training. When we discussed the value of this workshop among ourselves as agencies, we saw tremendous value in the sharing process. We need to hear from the physicians and physiologists, their ideas, their theories. We do not need absolute proof; we can deal with the implications of the material available now. We also are not a group constituted to make decisions and vote resolutions. Rather, we are here to share, to develop ideas, to be able to say: this needs research, or this is something that the agencies could work on together.

Mr. Stewart: I would feel morally lacking if I did not teach people in some open water situations. In reviewing the general diving accident statistics, it seems clear that if people had had any open water training whatsoever, they would not be statistics. The people I have trained to use open water techniques have a certain confidence level, and when they are performing in the open water, they really do not worry about it. They know that they can handle the situation. We have never had a problem, and a sense of security does develop in these people. There is a moral obligation to train people in the environment in which they will be working. This permits them to work with a much more relaxed mental attitude.

Dr. Egstrom: We have had two meetings of the diving officers (about 20 or 25 of them) from various institutions in the State of California and at both meetings the group concluded that they would continue to teach emergency ascent procedures because they feel they would be deficient in their responsibilities as diving officers if they did not do that.

The risk seems to stem from a loss of self-control that results in too rapid an ascent, whatever the physiological conditions are at the moment. The crux of the problem is the development of self-control necessary to be able to exercise whatever procedures are required. Second, any technique depends on self-control and an effective level of training. I believe that the biggest single weakness in this whole procedure of emergency training is a lack of adequate training. We have not put in the effort to ensure that these people will be able to execute the skill in a relaxed and confident manner. If ascent rate is the problem, then we will have to deal with ascent rate. If we do this, any alternative procedures have to be standardized first, over-learned second, and then reinforced periodically.

Mr. Samson: One training exercise is not sufficient to give anyone any confidence. We must recognize that there will have to be between 7 and 14 exercises before students are in the overteach curve.

Dr. Egstrom: Jim Stewart has commented for years that in the business of training a diver, until a diver has had 8 to 12 successful open water experiences, he is simply not trained. He is not a diver, he is still a novice through that particular range. We have been gearing our program for years to build in that kind of exposure. This is the trend; at present, we have 3 or 4 open water experiences.

Mr. Hardy: We analyzed all NAUI training accidents and found that virtually every single one of them happened on the first scuba experience in open water. These data are from our legal accident records.

Mr. Smith: We did an analysis of actual buddy breathing problems in operational situations, and then we looked back at the type of training of the individuals involved, both successful and unsuccessful, and we concluded that it was necessary to build into our recommended training outline approximately 17 exposures to buddy breathing to achieve the kind of proficiency needed for emergency performance.

Dr. Miller: In NOAA, we require 15 open water dives to attain the category of limited diver and 100 open water dives for unlimited diver.

Dr. Nemiroff: 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 overlearning 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. Therefore, I have no answer as to what the best emergency training technique is, but it seems to me we should strive for those that require minimum skill and minimum reinforcement and yet can still be considered valid exercises under the condition.

Conclusion

After further discussion, the group reached a consensus that open water emergency ascent training was not only important but highly desirable and morally justified.

PSYCHOLOGICAL PROBLEMS

It was generally agreed that a high level of stress that led to panic was responsible for most of the serious problems encountered in emergency ascent training. Dr. Egstrom stressed this point, and Dr. Harpur spoke of "those who develop air embolism because of panic and failure to follow any procedure."

There is unnecessary apprehension about developing air embolism, caused by scare tactics used in lectures and preliminary training. Dr. Harpur told of eight people "totally spaced out in panic because they had made a rapid ascent and were thoroughly expecting that they were going to drop dead despite the fact that some of these ascents were over an hour and a half prior to the time they arrived on our doorstep. I tell you this just to show the kind of expectations that most of the divers have with respect to the hazards of making a rapid ascent. They are terrified before they begin and if there is any better way to get somebody in a panic state, I do not know it. This is a big element we have to look at."

Dr. Overlock reported a "series of accidents and near-misses that occurred in San Diego when people opted for the wrong choice; accidents where someone would swim 40 yards under water to find his buddy so they could use buddy breathing. This is an example of just what we have been speaking of: people were not choosing their options appropriately, perhaps because of unnecessary fear." Dr. Harpur added some interesting observations about the fear of emergency ascent: there have been people on the bottom who have tried almost any alternative other than a self-propelled ascent, including doing such ridiculous things as swimming

25 feet deeper from the 50 foot mark, only to discover they could not get air from the buddy when they caught up with him, to swimming as much as 50 yards horizontally across the bottom after a buddy in 60 feet of water. All of these accounts make you wonder how badly biased we are against what may be the best remedy."

One of the ways to avoid panic is to overtrain so that in an emergency situation the diver follows the training pattern almost instinctively; there was general group agreement on this point. Several of the physiological considerations that follow have a psychological component, which must be considered as part of the total problem.

PHYSIOLOGICAL CONSIDERATIONS

Man as Air Breather

One of the first training problems is a result of the fact that man, an air breather, tends not to breathe under water. The tendency to hold the breath is accentuated in stressful situations, and leads to emotional instability and panic. In this connection, it is interesting (though not germane to scuba training) that the U.S. Navy has never had a fatality during free escape using the Steinke hood, and neither has the British Navy during escape training using its hood. In both cases the trainee has an ample air pocket surrounding the head so normal breathing is facilitated. But since hoods are not available to scuba trainees, it was important to consider possible physiological problems or constraints associated with emergency ascent training.

Hypoxia

First, the likelihood of developing hypoxia during emergency ascent was discussed. The development of hypoxia depends on:

The type and intensity of the diver's activity just before starting an emergency ascent;

The time at depth taken to make the decision -- the longer the time at depth without or with insufficient oxygen, the greater the likelihood of hypoxia;

The degree to which panic or emotional reaction increases metabolism and oxygen consumption;

The speed of ascent; and

The distance traveled.

Conclusion

Most of the conferees felt that the advantages of taking a few seconds' delay to determine the best method of emergency ascent far outweighed the questionable increase in the probability of developing hypoxia. On the other hand, time should not be lost in futile attempts to get to a new air supply; going directly to the surface in a controlled manner is usually the best choice.

Lung Pathology

One of the items in a diver's physical examination is a history of any respiratory disease or condition, and a thorough examination of the lungs, including an X-ray. But, despite the most thorough evaluation, there will still be deaths due to lung pathology. There was a discussion about whether or not scuba training students should be told that all pre-existing lung pathology cannot be ruled out at screening examinations, and that in certain emergency ascent situations some types of lung pathology could be fatal. Most workshop participants felt that this aspect of diving physiology should not be overemphasized, but Dr. Lanphier countered this argument by saying:

"We owe students this kind of information just as a medical researcher owes human subjects a clear and complete discussion of the possible risks of an experimental procedure. In ethics and law, the issue concerns informed consent, explicit or implied." Further, "We seem to agree on the necessity of certain types of examination -- Xray and auscultation of the chest at the very least -- that may reveal relevant chest problems. Students deserve to know why we recommend or demand these procedures."

Exhaling Ascent

As noted earlier, using an independent method of ascent requires the diver to exhale all the way to the surface. He is not able to use his breathing apparatus, and buoyancy for upward movement is gained from expanding air in the lungs. Theoretically, this is a satisfactory method of handling an emergency ascent, but it is difficult to learn to execute this maneuver properly. One of the discussants noted, "Air venting can be accomplished in a safe manner, provided near-maximal air volume is maintained in the lungs during ascents. With the lungs inflated, there is no tendency to inhale. One major factor causing panic is over-exhalation, which stimulates the inspiratory phase of the Hering-Breuer cycle to over-exhalation. In the conscious person (and based on experiments), I believe it is not possible to overdistend the lungs to the point of alveolar-vascular ruptures. The conscious individual 'splints' his lungs, and vents air so that injurious overdistension does not supervene."

Too great an exhalation on the bottom may necessitate an active swimming ascent because of lack of positive buoyancy. One recommendation was, "... the instant that an individual suspects that he is out of air or has any misgivings about his air supply, he begins to gently move upward while assessing it [the situation]."

Mr. Friedman said of this situation: "They [the divers] probably will notice that they have no air at the time when they have just finished exhaling. This is the biggest argument against exhaling ascents. If they begin to exhale they are going to reduce their lung volume. Therefore, obviously, I am not suggesting that they sit on the bottom and continue exhaling. I am only saying that step one is a very short process in which they begin to analyze their procedures. One of the reasons I suggest this phase is: a number of accidents have occurred where there has been only an apparent termination of air supply and no actual termination of air supply. There have been, for example, four cases of air embolism treated at the Miami chamber in which two had in fact air left in their tanks but water in their masks. They were misinterpreting the air situation. To inhale, what do you have to do? You have to exhale first, and there are, believe it or not, pretty strong suspicions that some people are actually hyperventilating due to stress and eventually, therefore, are pulling too much air in. Their lungs are full but they are under such stress that they do not realize it and they try to inhale. They are not getting much or they are getting no air at that point; they interpret this as no air supply. What I am saying then is that if they exhale, they will at least open the glottis, they will be in a position where they will be able to ascend safely."

Several other participants confirmed this statement by reporting that "... in the vast majority of all out-of-air situations, [the divers] were really not out of air." In the Rhode Island Accident Center statistics Mr. McAniff found that, "There are many instances when they [the divers] thought they were out of air but were not."

Conclusion

The group generally agreed it was best to start an ascent to the surface using breathing equipment, for often there is plenty of air. In fact, even if there actually is no air left, it is better to leave the mouthpiece in because the very act of attempting to breathe helps psychologically and is better than going to the surface attempting to exhale. The attempt to breathe keeps the larynx open; swallowing is also helpful.

Laryngeal Spasm

This condition is most serious and is "responsible for 16% of all drowning deaths." According to Dr. Samson, "Laryngeal spasm lasts until you die. It is not controllable." The type of obstruction to the airway is generally inspiratory. Dr. Samson maintains, "In most cases the cords will tend to collapse down and the movement of gas is impeded from going in, but frequently you can get gas out by squeezing the chest. This would not be a recommendation in the unconscious person. The big problem in a laryngeal spasm is to get air in. Oxygen is the best and the foremost treatment for laryngeal spasm. You have to force it into the patient." Others said that laryngospasm will relax spontaneously if the irritating cause is removed.

Head Tilt - Conclusion

One of the dicta in training has been that during an emergency ascent, the head must tilt back as far as possible to ensure an open airway. There was general agreement among the physicians that in the conscious person, there is no need to tilt the head -- the airway is open no matter what the position of the head. Only in the unconscious person is it desirable to tilt the head back to ensure an open airway. It is certainly permissible for the conscious person to look upwards during ascent to avoid any obstruction.

The training groups were quick to grasp the significance of this physiological information, and were eager to translate this into training practice.

Gas Flow

Another concern was the rate of gas flow from the lungs, which is determined by three factors at the beginning of the ascent: depth; lung volume at start; and rate of ascent. Consideration must be given to the mechanism of respiration under ascent conditions, the uniformity of gas flow in the airway, and compliance. However, there is probably no depth limitation associated with these physiological considerations, and the rate of ascent is also probably not limiting. The British, using the hood, have increased the ascent rate from 1 ft per second to 10 ft per second and there does not appear to be any limitation in terms of ascent rate. This might be different if one started with a full lung.

Need for More Physiological Knowledge

Dr. Lanphier made the following statement: "Very few changes in current emergency ascent doctrine and training procedures can be recommended on the basis of present physiological knowledge. It is also important to warn against making changes on the basis of untested physiological theories. The need for renewed physiological investigation relative to emergency ascent was stressed. Reliable new information could have profound effects upon what is taught and how training is conducted.

"The degree of risk of hypoxia in swimming ascents needs to be assessed, particularly considering situations where the diver has been working unusually hard before ascent or delays the beginning of the ascent.

"It is clear that decision-making before ascent must be minimized to avoid undue delay. The maximum safe depth for swimming ascent cannot be specified without further consideration. Significant risks of hypoxia in swimming ascent would favor ascent procedures involving buoyancy.

"The rate of total pulmonary gas flow during ascent is a function of lung volume as well as of rate of ascent. Changes in procedure that would increase average lung volume during ascent would call for renewed consideration of the possibility of excessively high flow rates in terms of airway resistance.

"The uniformity of elimination from different areas of the lung deserves study in the light of present understanding of local airway closure and related phenomena, including the implications of abnormal compliance. It is not unlikely that new information in this area would warrant important changes in ascent doctrine and training.

"Detection of pulmonary abnormalities in prospective trainees is extremely important from the physiological standpoint. Additional attention should be directed to the significance of factors in the medical history such as smoking, childhood asthma, and recent respiratory infections. Experimentally, attention should be directed toward seeking valid screening procedures that could be applied with minimal cost and effort.

"It should be recognized that accidents that cannot yet be explained do occur even when ascent training is performed under the best possible supervision by subjects who have passed the most extensive physical examinations. Attempts must be made to identify the cause of such accidents in the hope that something can be done to prevent them. This implies that we should try to find out what actually is going on in these situations in case there is something we can do about it."

[Dr. Lanphier believed that the discussion of physiological factors had been too drastically shortened in the editing process; the remarks that follow expand on his workshop comments.]

"The most vital need for additional physiological information concerns the optimal lung volume during ascent. The implications of such information for training are probably obvious. Some of the physicians and physiologists present believed that maintaining a relatively low lung volume entails a risk of regional airway closure with consequent trapping of expanding gas. This concept is based on the accepted fact that airway closure occurs as exhalation proceeds. ("Closing volumes, etc."). Others, including myself, think it is at least equally likely that expansion of gas will cause natural reopening of any closed airways and that trapping by this mechanism will not occur. No one has a valid answer since the necessary research has not been done.

"The volume question is important because deliberately maintaining a high lung volume during ascent will increase the volume and flow rate of expanding gas, and this may increase the likelihood of overinflation.

It also largely eliminates the margin for safe expansion in the event of momentary interruption of flow. Recommending a procedure involving high lung volume without clear experimental evidence seems irresponsible.

"Other things being equal, higher lung volume would have the desirable effect of increasing the quantity of oxygen available to the body during ascent. This brings up another physiological "area of ignorance." We do not know how great the risk of hypoxia would be under various conditions of unassisted swimming ascent. We should obviously not train divers in a procedure that would often lead to loss of consciousness from lack of oxygen before reaching the surface.

"Calculations based on existing knowledge would give us a better idea, for example, of depths from which safe swimming ascents might ordinarily be made. To the date of the workshop, such calculations had apparently not been made. In any event, there are so many possible variables that few positive conclusions would be justified. This line of reasoning suggests that the optimal ascent procedure will include some means of gaining buoyancy."

The discussion then turned to how to take advantage of the information available to make ascent training safer and even more efficient.

WORKSHOP COMMENTS ON ASCENT TECHNIQUES

During the workshop, participants commented on various aspects of specific ascent techniques. These have been taken from the transcript of the meeting and grouped according to technique. These comments are not intended as endorsements or recommendations of specific ascent procedures. It is hoped that organizing these comments according to technique will encourage each reader to make his or her own evaluation of ascent procedures, based on the knowledge (admittedly scarce) available to date.

Dependent Action Ascents

Equipment-assisted ascents (octopus rig).

1. Once the second stage or octopus regulator is placed in the diver's mouth, it should remain in the mouth throughout the entire ascent.
2. It is essential in octopus breathing that the two buddies stay fairly close to each other.
3. In some dive situations, such as being caught in a kelp bed or when one diver has no air but the other has plenty and both need decompression stops, octopus breathing is a good solution.
4. It is easier to use the octopus technique in the Caribbean, i.e., warm water, than in Puget Sound, because cold water slows

physiological responses, and the necessary hand and mouth movements are much more difficult to make; both tactile sensitivity and muscle strength decline significantly in cold water. The colder the diver, the more severe these physiological problems become.

5. Octopus breathing allows good buddy-to-buddy communication, because eye contact is maintained during ascent.

6. Octopus breathing ascent procedures resemble normal ascent procedures more closely than other emergency techniques, and thus are more likely to be used in an emergency.

7. The fact that octopus breathing involves a second diver means that the second diver is at increased risk during the ascent; this disadvantage can be offset, at least somewhat, by maintaining a face-to-face position during ascent.

8. It is important to remember that in <u>any</u> buddy diving situation, when one diver is out of air, the other is probably also nearly out of air. In a panic situation, there is a great increase in the amount of breathing gas required; these factors can easily combine to produce a disastrous situation.

9. In very cold water, the first stage of the regulator may freeze up completely.

10. The octopus technique generally requires less training and less skill than shared-air buddy breathing techniques.

11. Before depending on the octopus technique, it is important to establish that the UBA will support the divers' demands; for example, in a panic situation a diver may require as much as 350 liters of gas a minute, a demand beyond the operational capability of most equipment when the tank pressure is below 300 or 400 psi.

    a. Since a person's respiratory response (and therefore air requirement) to stress is the same under water as on the surface, it is possible to establish individual requirements by surface testing.

    b. Flow data are available for some types of equipment.

    c. Octopus equipment should be standardized, e.g., length of hose, type and position of regulator, to make using the technique easier in an emergency.

Buddy-breathing ascent.

1. Comments 2, 3, 4, 5, and 8 (under the octopus rig heading) apply also to buddy-breathing.

2. Continual practice is necessary to perfect and maintain buddy-breathing skills.

3. The breathing pattern fostered by this technique is conducive to breath-holding, since the diver does not breathe during the interval when the buddy is using the regulator. During ascent, this breath-holding may increase the probability of pulmonary trauma.

4. Buddy breathing is particularly risky in situations in which one of the buddies has panicked; the diver in distress may cause the death of the buddy attempting to rescue him.

Independent Action Ascents

Buoyant ascent.

1. The diver's control and mobility are limited in this kind of ascent.

2. Ascent rate varies in this type of ascent, depending on the amount of positive buoyancy and the amount of drag produced by the equipment; through the shallow end of the water column, the diver is accelerating during ascent.

3. There is no orientation problem, i.e., no chance of going down rather than up, with buoyant ascent.

4. Buoyant ascent cannot be used unless access to the surface is unimpeded.

5. There is a danger of entanglement, e.g., in kelp, when using this ascent technique.

6. When the buoyancy device is inflated and during ascent, the device may become so tight that it is difficult to breathe. Breathing against the positive pressure inside the suit may also be difficult.

7. This method of ascent requires almost no work on the part of the diver.

8. Sources for achieving buoyancy must be considered carefully if the diver finds himself/herself out of air. It may be possible to use oral inflation, and it may also be possible to breathe from the buoyancy compensator, although this technique is not taught in training because it is too complex.

9. At present there is no standardized equipment for buddy breathing.

10. This ascent technique requires careful and thorough training, but it is less complicated than the technique for swimming ascent.

11. Psychologically, this method may be reassuring because the diver knows he/she is heading for the surface, but this advantage is probably offset by the fear of developing an air embolism.

Swimming ascent.

1. In a non-buoyant swimming ascent, it may be difficult to maintain a sense of direction.

2. Lack of buoyancy is the greatest disadvantage of this technique.

3. Using this procedure, it is possible to maintain a standard (60 fpm) ascent rate.

4. Humming during ascent is important, because it keeps the glottis open.

5. The conscious diver's head does <u>not</u> have to be tilted back to maintain an open airway during this type of ascent.

6. Bubbles in the water are an indication that the diver is exhaling during ascent, and they also point the way to the surface.

7. The regulator should not be removed from the mouth during a swimming ascent, since attempts to inhale through it may help rather than hinder.

8. The skills required by this technique are easier to learn than those for the dependent ascents; only a limited degree of motor-skill coordination is required.

9. It is difficult to assess lung volume and to control it during this type of ascent.

10. This technique may predispose to breath-holding because the diver fears he/she has inhaled too much air.

11. Swimming ascents require no other persons or special equipment, and they may be performed equally well in all environmental conditions.

12. The procedures required by this ascent technique approximate those of a normal ascent more closely than other ascent techniques do and are therefore more likely to be remembered in a stressful situation.

GENERAL COMMENTS

1. Swimming ascent training depth limits.

The training agencies represented at the workshop restrict swimming ascent training to depths of 40 fsw (one agency), 30 fsw (2), 20 to 40 fsw (1), 20 fsw (1), and 15 fsw (1). This depth range was not considered excessive for safety.

Training depths are chosen with an eye to giving trainees experience and at the same time avoiding undue risk. Statistics show that hazard increases with depth. However, since the choice of training depths now being used cannot be supported by experimental data, the group was unable to recommend any depth range for non-buoyant swimming ascent training. Most training agencies feel that basic scuba divers should not dive to depths deeper than 100 fsw, and that advanced scuba divers should not venture below 130 fsw; some agencies specify the 130-fsw depth only, without regard to level of diver training. It stands to reason that an agency's emergency ascent technique ought to be suitable for the maximum diving depth allowed by the agency in question.

2. Control of ascent rate.

It was formerly believed that dropping the weight belt would cause the diver to "rocket to the surface." In fact, from a kneeling position at 30 fsw, a non-swimming diver without weight belt will reach the surface in about 20 seconds at a rate of about 120 fsw/minute. If a diver "flares" (extends both arms and legs) during ascent, this rate can be reduced to about 70 fsw/minute, particularly if the diver wears a wet suit, Farmer John jacket, hood, boots, and gloves. Even with the flare position, however, the ascent rate may be very rapid for the last 10 fsw. Divers should learn to control their ascent rates as much as possible. It is estimated that in 85% of diving fatalities related to ascents, the divers did not drop their weight belts.

3. Medical facilities during training.

Although all the workshop participants agreed that it would be desirable to have a hyperbaric chamber at every training site, this is not feasible. However, it is possible and desirable to have an oxygen resuscitator on site during emergency ascent training.

CONCLUSIONS

Workshop participants agreed that the discussion had highlighted the degree of ignorance that still prevails about emergency ascent training, techniques, and physiological responses. The group agreed that research designed to answer some of the questions raised is urgently needed, and that more accurate accident data would help in program planning. Greater standardization of emergency ascent training and equipment was also recommended by the group.

The major conclusions of the discussants were:

1. Despite the statistically small risk associated with emergency ascent training, the training agencies should continue to offer this training.

2. The voluntary and informed acceptance by the trainee of the agency's offer to train him/her in emergency ascent techniques implies an acceptance of the risk involved.

3. Every effort should be made by the training agencies to improve training techniques to minimize the risk associated with training; thorough screening of ascent training applicants and intensive and careful emergency ascent training are examples of procedures likely to reduce this risk.

Finally, the workshop participants agreed that it was essential for the training agencies and physiologists to stay in contact, so that the discussion begun at this workshop might continue.

SECTION II

INDIVIDUAL PAPERS

FREE ASCENT TRAINING
(Outline)

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I. INTRODUCTION

A. THE PROBLEM: "Free Ascent Training." Is its inclusion in sports SCUBA diving classes indicated?

B. BASIC DEFINITIONS:

1. Ascent
    - a. Normal
    - b. Emergency
        - (1) Controlled
            - (a) Free (monitored exhalation)
            - (b) Buoyant
                - 1 Non-hooded
                - 2 Hooded
            - (c) Swimming
                - 1 Non-equipment assisted
                - 2 Equipment assisted
            - (d) Combinations
        - (2) Uncontrolled: (Panic, air trapping, excessive buoyancy)
2. Panic
3. Alternative Emergency Ascent Methods
    - a. Buddy breathing
    - b. Vest supply

c. Pony system

d. Octopus

e. Personnel transfer capsule

C. CONSIDERATIONS

1. Optimal preparation - minimal risk

2. Legal

3. Economic

II. BODY

A. BACKGROUND

1. Peirano et al. 189 Thousand Simulated Escapes (about 1 EAA per 100,000 trials).

2. Ingrum (personal communication), about 3,000 Free Ascents in BUD/S, Training Coronado, CA. No EAA Problems; 200,000 Ascents Submarine Base NL, CT: 30 Emboli; 12 Deaths.

3. Nemiroff, 4 Cases of Pulmonary Barotrauma in Training Accidents Occurring Under Strict Supervision of Well Qualified Diving Instructors.

4. Graver, 63,000 Emergency Ascent Trainings in Sports SCUBA Divers with No Lung Expansion Injuries.

5. Rhode Island 1974 Accident Study: One Accident in over 200,000 Certifications.

6. Strauss & Ingrum, in An Estimated One Hundred Thousand Special Warfare SCUBA Dives over an 8 Year Period. One Air Embolism Case Recalled. All Trained in Free Ascents.

B. OBSERVATIONS

1. Risks are associated with any practical diving evolution.

2. Grave diving problems are associated with errors made during ascent. Usually the errors are precipitated by an emergency.

3. Panic control and condition training reduce likelihood of errors during emergencies.

4. The objectives and situations for U. S. Navy Emergency ascent training are different than those for the sports diver.

5. SCUBA diving is a kinesthetic experience and its training requires practical skills.

6. Requirements for emergency ascents from different depths are not the same.

7. Pulmonary barotrauma diving emergencies are virtually never observed in those divers trained in emergency ascent techniques.

C. EMERGENCY ASCENT TRAINING

1. Didactics

   a. Definitions

   b. Indications

   c. Methods; body and head position, rates of ascent

   d. Physics and physiology of EAA's

   e. Training evolution (cf. 3 and 4 below)

   f. Extra-alveolar air syndromes

2. Medical Evaluation

   a. History

   b. Physical exam

   c. Chest x-ray

   d. Special tests (based on age, findings from above three exams, etc.)

3. Pool work

   a. Harassment drills

- b. Breath-holding underwater trials and swims (confidence builders)
- c. Ascents from breath-hold dives, shallow to deep water
- d. Ascents with SCUBA, shallow to deep water
- e. Simulated emergency controlled swimming ascents (SECSA's)

4. Open water
    - a. Diving conditions - must be near ideal
        - (1) Surf
        - (2) Visibility
        - (3) Temperature
        - (4) Anchor line
            - (a) Float on surface
            - (b) 30 lb wt. on bottom
        - (5) Octopus rig on instructor's manifold
    - b. SECSA's (Simulated Emergency Swimming Ascent)
        - (1) Depths
            - (a) 10 feet
            - (b) 20 feet
            - (c) 30 feet
        - (2) One student-one instructor
        - (3) Student with one hand in contact with anchor line at all times; holds regulator in other hand. Should any problem be realized the trainee should hold fast on the anchor line and resume breathing with his regulator.

III. CONCLUDING REMARKS

A. SUMMARY

Virtually every training evolution in diving has elements of risk. The risks vary with the type of evolution, the sophistication of the teaching methods, the environmental conditions, etc. Consequently, the risks vs benefits of each training evolution must be weighed and then utilized accordingly.

The benefits of simulated emergency controlled swimming ascent training outweigh the risks. The gravest diving medical disorders are those associated with errors made during ascent. These are often precipitated by an emergency. Since equipment for immediate, definitive treatments is not available at the scene of an accident, the only realistic method of dealing with such problems is through education, practical training, and prevention.

Merely discussing the subject of open water emergency ascents is insufficient training to prevent potential catastrophes in emergency ascents. SCUBA diving is a kinesthetic experience. Divers do not master this sport until they have open water diving experiences. This is true for SECSA's also.

SECSA training needs to be introduced early in the diving curriculum. It should be started with swimming to the bottom of a pool while breath-holding and ascending in a SECSA fashion. The next step in the progression is SECSA's in a swimming pool with SCUBA gear. The final step is progression to open water. In open water SECSA rigid safety criteria must be followed including ascent on an anchor line, one student to one instructor ratios, shallow to deep trials, etc.

In my observations emergency problems of ascent have been virtually non-existent in those training programs that have placed emphases on conditioning and practical skill as well as didactics.

B. GUIDELINES FOR EMERGENCY ASCENTS

DEPTH	METHOD	MISCELLANEOUS
0-50 feet	Controlled, swimming	
50-130 feet	Octopus or pony rig	Anchor/descending line
> 130 feet	Transfer capsule	Recompression chamber on surface

IV. PROSPECTIVES

A. STUDIES

1. Occurrence of air embolism in patients with and without SECSA training, retro and prospective.
2. Conditioning parameters/requirements for divers
3. Harassment training methods and their role in preventing panic and air embolism

B. INFORMATION DISSEMINATION METHODS

C. REFERENCES

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5. RHODE ISLAND ACCIDENT REPORTS. 1974. University of Rhode Island, Kingston, RI.
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EMERGENCY ASCENT TRAINING
THE SEVEN YEAR RECORD, 1970-1976

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In preparation for this special workshop on Emergency Ascent Training, a review has been made of all seven years of records at the National Underwater Accident Data Center at U.R.I., with special attention to the 80 recorded fatalities which occurred during formal training programs, that is, those associated with recognized national certifying agencies. This group of 80 fatalities revealed 20 cases which occurred during emergency ascent training (25%). Ten of these were during "buddy breathing" exercises, nine occurred while performing "emergency swimming ascent" drills, and one occurred while attempting a drill with an "octopus rig."

Of the twenty identified cases, five occurred in 1976 and four in 1975, for a total of almost fifty percent in these two years as compared to the entire previous five years. In addition, there were eight to ten cases within the 80 training fatalities in which information available was insufficient but strong suspicion existed for the belief that some sort of emergency ascent training was underway leading up to the accident.

Most of the emergency ascent training fatalities took place in the depth range of 20 to 40 feet. (National agencies vary in their suggestion as to the depth for such training but none recommend deeper than 40 feet.) However, three of the cases were in excess of 40 feet and one of these was conducted from 65 feet. One of the 20 cases was recorded in the 16-feet-deep diving well of a swimming pool facility.

The following account will be found in the yet to be published report on U. S. Underwater Fatalities, 1976: "The accident took place on the second open water training dive in a tropical area. The class consisted of eleven students and one fully trained diver to round out for equal buddies. They were supervised by the major instructor and an additional fully certified instructor assisted by three advanced open water safety divers. Following some fifteen-foot-deep snorkel diving, an extensive briefing was given by the major instructor and a dive was made to 65 feet. This was followed by ascending to a flat ledge at a depth of 25 feet, from which depth the exercise of exhaling ascent was to be conducted. The instructor successfully took the first student through the ascent and after checking on the surface that everything was alright, they returned to the 25-feet-deep ledge. The next student was waiting and after the O.K. signal was returned, the instructor gave the 'go up' signal. The student removed his mouthpiece and with the instructor holding the student's harness with one hand they proceeded to the surface at an apparently proper rate of ascent. On the surface the student was asked 'Are you O.K.?' and he replied 'I'm fine'. A couple of seconds later the student threw his head back, made a strange gurgling noise and began to sink. He was grabbed by the instructor, who immediately inflated his own vest. The other instructor had just surfaced nearby and came to their assistance. As they started to shore, it became obvious that the victim was not breathing, so they made for the nearest shore contact, only to be tossed repeatedly by wave action. During this period mouth-to-mouth resuscitation was given intermittently and upon acquiring solid ground heart massage was started. Continuous CPR was conducted until the helicopter arrived and on board the helicopter all the way to the hospital, without recovery. The autopsy showed 'multiple areas of pulmonary rupture' and 'air embolus of the left ventricle of the heart'".

It would appear that just about everything was done correctly in the above account, but the result was still a fatality.

In retrospect, for many years we have taught the buddy breathing technique but there are indications that it doesn't work in a true emergency if it has not been practiced by the two buddies for some time. The octopus or spare second stage regulator system and/or a pony bottle system have been advocated by many and we have on record only two cases in which the octopus system was available both of these resulted in fatalities. One of these cases involved a double death in a cave. The other occurred during a training exercise. The exhaling swimming ascent seems to be the other available alternative presently being taught, but in 1976 three fatalities were recorded while training in this method.

A strong argument has been advanced in favor of both of the above methods of emergency ascent, based on the many divers trained over the years versus the small number of deaths. However, I submit that NO death from this type of training is the only acceptable record.

MINIMUM STANDARDS OF PERFORMANCE FOR BASIC SCUBA DIVING STUDENTS

Robert K. Overlock, M.D.

The open water checkout is now considered a necessary part of any basic SCUBA diving course. These minimum standards are applicable to this ocean experience under direct supervision of the instructor and/or his assistants. It must be understood that the background, preparation, and training of each student have equipped him to cope with each of the following exercises without any marked difficulty. All of the techniques and details of carrying out the exercises are left to the professional judgement of the instructor. Our purpose is not to arbitrarily impose, but to define for our own guidance and mutual protection those practices that we collectively feel contribute to minimal standards of demonstrable student skills that can be expected from the basic SCUBA diver. This level of skill achievement should help to establish the student's self-confidence, and display to himself and the instructor that he is ready to acquire additional experience without professional supervision.

In order to meet our standards, the basic SCUBA diver should perform the following exercises without difficulty or development of serious problems:

1. Make an appropriate surf passage (entry and exit) wearing full ocean SCUBA diving equipment and swim 300 yards on the surface using a snorkel breathing device.

2. Flood and clear the mask while submerged.

3. Flood and clear the breathing apparatus.

4. Demonstrate "buddy breathing" both as a donor and recipient.

5. Demonstrate a free swimming ascent from 25 feet or more, exhaling all the way to the surface.

EMERGENCY ASCENT TRAINING

Charles V. Brown, M.D.

I. Introduction

More than half of the divers responding to a recent survey reported having had a life-threatening experience after certification. Urgent ascent was often required, and many confessed to panic.

Some of the greatest hazards in scuba diving are inherent in ascent, and emergency conditions compound the danger. Training minimizes it, but one aspect of emergency ascent resists training. It is the need to avoid breath-holding. This is the one imperative for which nothing in the student's past has prepared him. On the contrary, instinct demands that he hold his breath while submerged, and any experience he's had with underwater swimming confirms the necessity. Therefore it is essential that he be thoroughly indoctrinated in safe ascent techniques, and also that he practice, for the body must learn as well as the mind. Indeed he must be over-trained, so that the residual skill remaining if panic strips the superficial layers will be enough to save him.

It is important to agree upon what to teach divers so that they'll have the best chance of surviving, and so that divers with different certifications will react to emergencies in the same way.

II. The Setting

All divers encounter situations which seem threatening. These include loss of air, flooding or loss of a mask or inability to clear it, sea conditions such as darkness or violent surge, presence of dangerous marine life, actual attack or envenomation, and bodily distress (self or buddy) such as choking, dizzyness, hysteria, seizure, acute dysrhythmia, heart attack, or collapse for any reason. Immediate surfacing is not always the best response, but the novice or emotionally unstable can think of nothing else.

The commonest event compelling emergency ascent is loss of air supply. Sometimes it's only imagined, but divers have found an amazing variety of ways to make it real. They select near-empty tanks thought to be full. They lose both tank and regulator from a loose back pack. Regulators clog with rust, or with carbon powder from a defective air station filter. A loose first stage leaks, or second stage free-flows (including octopus). The regulator entangles and cannot be found or freed. A slightly opened tank valve delivers adequate air flow in shallow water, but seems to shut off at depth. A gauge or alarm malfunctions, or a J valve is tripped without its being known. Air consumption is too rapid because of unplanned hard exertion or cold or apprehension, or sharing with a buddy. A regulator is purloined by a big lobster or octopus who won't give it back. Or one's buddy won't give it back. All these have happened.

III. The Options

Methods of getting a diver up are many, but they vary fundamentally in only three respects: agency, propulsion, and breathing. Agency refers to who's in charge - the diver in trouble, or a rescuer. The ascent may be independent, wholly dependent, or partly dependent. A safe independent ascent implies a diver who is conscious and functional, and has the resources to stay that way. In a totally or partly dependent ascent, someone else assists with propulsion and/or ventilation.

Means of propulsion include swimming, rope climbing, towing, and buoyancy. Positive buoyancy can be achieved by ditching weights, expanding one's lungs, or inflating one's dive suit or personal flotation device. The latter are of myriad design and may be inflated by mouth, by push button (tank air), or by releasing CO_2 or compressed air from a separate container. One model even inflates automatically if a diver fails to breathe.

If one's primary source fails, he may breathe from a redundant supply such as a second tank or pony bottle via a separate regulator or a B C vest. He may obtain air from another diver by the same means, or by buddy breathing or octopus regulator. He may re-breathe his own air, using his B C as a breathing bag. Finally, he may breathe residual tank air as ascent reduces ambient pressure and makes it available. For each 33 ft. of ascent, a standard steel tank yields .42 cubic feet surface equivalent. This isn't much in deep water, but becomes appreciable as one nears the surface and his need to ventilate becomes acute; e.g., a tank apparently empty at 33 ft. should deliver a liter of air after 6 ft. of ascent.

When inhalation is impossible, the ascending diver must still vent air to avoid increased intrathoracic pressure which would tear lung tissue and/or render him unconscious by decreasing venous return to the heart. If he commences his ascent promptly he'll have a high partial pressure of O_2 in his lungs, and venting air will remove CO_2 as he goes. Thus he can expect to remain functional considerably longer than would be predicted from his breath-holding time at the surface, under the same condition of exertion.

IV. Further Technical Considerations

A swimming ascent adds to one's O_2 need and CO_2 burden, and the amount can be great if buoyancy is negative. Wet suit expansion adds a progressive buoyancy factor. Weight ditching adds a constant and also irrevocable factor. Variable volume devices allow limited control of buoyancy, but require dexterity and close attention. Altering one's lung volume affords a 5 to 10 lb. range of buoyancy control but is dangerous. Low volumes predispose to airway closure (more on this later). High volumes permit free venting, but any unintended block as from swallowing or laryngospasm would quickly produce over-pressure. Climbing an ascent line permits optimal control and makes buoyancy unimportant.

A buddy-breathing donor should maintain physical contact with the recipient by holding on. He may also wish to maintain physical control of his regulator. The parties may face each other, or the donor may station himself behind or to one side. The former method permits direct observation and reassuring eye contact. The latter avoids having to flip the regulator 180° with each exchange, and is much easier when ascent is not vertical. It must be remembered that each time either party surrenders the regulator, he's making a breath-hold ascent and must vent.

Using a B C vest as a re-breathing bag permits cyclic chest movements and so lowers the breathing urge and perhaps the tendency to hold one's breath. However, it adds a lot of buoyancy, requires frequent breaks for venting, and imposes some risk of getting water into the mouth and throat. Many B C mouth pieces are unsatisfactory for such usage.

An unconscious, non-breathing diver should not be inverted for ascent. Not only is foot-first awkward, but inverting him would reverse the mouth-to-lung pressure gradient and water would enter the mouth. (Possibly far enough to cause laryngospasm.) Note: laryngospasm prevents or severely restricts inhalation; it restricts exhalation somewhat less, but still severely and certainly enough to cause lung over-pressure and blowout during ascent.

If the mask is partly flooded it must be removed lest the expanding air push the water down his nose, again triggering laryngospasm. Tilting his head back, as often recommended, seems risky. It might conceivably allow water to trickle down the nose or mouth to the throat, even while air vents out. And it seems unnecessary, for the obstructing effect of a lax jaw and tongue, even with neck flexion, and largely one way: it retards exhalation far less than inhalation. On the other hand, an unconscious diver who is breathing should have his head tilted back to facilitate inhalation.

V. The Choice

Circumstances both limit one's choices and dictate the best. In deciding between independence and dependence, one must consider his air reserve, and degree of exhaustion, buoyancy control, overhead obstacles, time to surface, time to buddy, and buddy's potential for aid. In practice the decision is often automatic. Even experienced divers faced with sudden loss of air frequently blast off on a fast independent ascent, ignoring an agreed-upon dependent alternative. The choice is usually appropriate. If one feels he has a chance to make it on his own, the odds probably favor an attempt. It is the simplest and fastest way to go.

The success of a dependent attempt is harder to predict, for it hinges upon getting a buddy's attention and cooperation, and upon the skill and emotional stability of two people. An attempt may be warranted if one's buddy has an octopus regulator, but rarely if he doesn't. There have been a number of buddy breathing failures, some with double fatalities. The technique is difficult for most, and if one hand is used to control buoyancy or to hold a light, it may become virtually impossible. Still, if a partner is close and both parties are practiced and stable, buddy breathing can be simple and safe. And there may be no option in wreck, cave, ice, or kelp diving.

The complexities and risks of B C re-breathing are rarely justified. In an extreme situation, however, air exhaled into the vest at the onset of a long ascent could provide essential oxygen near its end.

Ascent rate should be as near standard as urgency permits. Where feasible, propulsion should be by swimming. This permits easy control of both rate and direction, places a fairly safe limit on rate, and is most familiar to most divers. Negative buoyancy should be avoided. Mildly positive buoyancy is indicated for a tired diver who starts with O_2 debt and high CO_2. Maximum buoyancy is justified if hypoxic blackout is feared, though the trade-off is heightened risks of lung tear and decompression sickness. Should the diver realize he doesn't need the speed, he can reduce it rapidly by assuming the flare position. If the way to the surface is not straight up, buoyant ascent is ruled out.

An incapacitated diver must be assisted, and since it is not feasible to help him breathe, aid will be limited to propulsion. Towing is advocated by most, and should be head first. If he's breathing, his regulator should be supported in his mouth, and his head tilted back. If he's not breathing, speed becomes the overriding concern. Indeed if one believes the victim near death from asphyxia, and there's no overhead obstruction, a strong case can be made for a fast buoyant ascent. The rescuer follows as quickly as he considers safe.

VI. What To Teach

The greatest impediment to safe emergency behavior is panic, so it is most important that the student acquire confidence based upon self reliance. We must also instill in him an attitude of concerned responsibility for his buddy. Though avoidance of emergencies has first priority, we must assure that the diver has the means to cope when they do arise.

As to equipment, a tank pressure gauge and a means of buoyancy control constitute the minimal requirement. A totally redundant air supply should be carried when the surface is not easily attainable by a non-breathing ascent. Other gear will be dictated by circumstance or preference. As to skills, we must seek the best compromise between ease of choice and execution on the one hand, and completeness of repertoire on the other.

Since panic inhibits rational thought, it makes sense to provide the novice with a simple framework for choosing his initial response. That recommended by the National Scuba Training Council gives him two independent options - swimming vs. buoyancy, and two dependent options - octopus vs. buddy breathing. We further recommend the concept of "total awareness." If a diver remains aware at all times of where he is, the potential escape routes, and the options available, he'll have far less difficulty making decisions under duress.

All aspects of emergency ascent should be discussed in class. Those methods most applicable to the type of diving the student will do should be practiced till thoroughly mastered, and periodic reinforcing should be arranged for. Every student should become adept at controlling his ascent rate while swimming, while utilizing buoyant assistance, and while going hand over hand up a line. He should practice the flare, and should have the experience of towing and being towed. And he should be trained in buddy breathing and air venting ascents.

Buddy breathing should be taught not because it is a favored technique, but because it may sometimes be the only way to go. On one occasion, four divers shared a single regulator from 100 ft. to the surface. It was an actual emergency, and for three of them, it was their first scuba experience outside of a pool. This illustrates what really thorough pool training can accomplish. As a bonus, buddy breathing instills the habit of purging a regulator before inhaling through it - a skill that carries over to using an octopus, or one's own regulator after it's been out of his mouth.

For emergency ascent, the single most valuable insurance policy we can give a student is mastery of the non-breathing, air-venting method. In most out-of-air situations, there is no option as safe, or no option at all. Octopus or buddy breathing attempts which fail become air-venting ascents. The technique has saved countless lives, and yet, performed improperly, has cost many. All active instructors have seen a student get a little water in his throat, spit out his regulator, and claw for the surface. If he reverts to instinct and holds his breath, tragedy is likely. The earlier he is in his diving experience, the more likely this is to happen. Therefore the basic student should practice supervised air-venting ascents from his first scuba experience. This seems so obvious as to defy dissent, and yet cogent dissent has been raised. The issue deserves careful analysis.

VII. Analysis of the Air-Venting Ascent

Years ago it was observed that panicked divers were holding their breath and embolising. Instructors began to emphasize the importance of exhaling during ascent. Responsible agencies recognized the problem, and the point was really pushed. With the Navy it was blow and go. With sport divers, it was exhale or die. Then a strange thing happened. Students exhaling at a normal rate and visibly blowing lots of bubbles all the way would embolise anyway. So quite reasonably, voices were raised against this type of training. The critics admitted that a real emergency air-venting ascent would be safer if practiced beforehand, but felt the likelihood of such emergencies arising too small to justify making students practice.

That conclusion was necessarily conjectural, for although we have some idea of the accident rate in classes, we have only a vague notion of the accident rate during real emergencies. Those with wide experience in sport diving know that most divers do encounter emergencies, and fear that discontinuing ascent practice would result in a much higher accident rate.

Nonetheless, we agree with the critics that practice as often conducted in the past should be abolished. Instead, practice should be conducted in a safe manner. This is possible, for we now know a great deal about the reasons for embolising accidents and how to prevent them. The accident rate in the New London submarine escape training tower in the period 1930-1954 was about 1 in 1,000 for free ascents, but only about 1 in 20,000 for Momsen lung ascents, even though the latter were much faster. And during two years out of that same period, when tower operations were under control of a medical research officer, 20,000 ascents were made with no casualties at all. It seems inescapable that non-breathing ascent involves more risk, but also that the training method used affects the risk.

In sport diving, the British Sub Aqua Club reported an estimated 15,000 air-venting ascents without incident. Many U.S. instructors with extensive experience have never had an incident. There must be a reason. We are aware that X-ray and EEG surveys have shown evidence of sub-clinical accidents, but we will try to show that any accident which would not result from normal breathing ascents need not occur in air-venting ascents either.

Lung tear with embolism is caused by over-stretching of alveolar walls when expanding air cannot vent off. The obstruction to air escape can be at the glottis, stressing the lung as a whole. Or it could be at a lower level, stressing the lung either generally or regionally. Embolisation that occurs in the absence of breath-holding (or rarely other upper airway blockage) implies small airway obstruction. A number of factors predispose to such obstruction by encroaching on the lumen. First, immersion causes a net blood shift of something like 700 ml. of blood into the chest. Cold-induced vasoconstriction, and the squeeze of a tight wet suit, would add to that figure. The lung gets some of that blood at the expense of airway volume. Second, wet suit squeeze would be expected to raise the diaphragm and constrict the thorax, further reducing lung air volume. Third, the upright posture creates a hydrostatic pressure differential between the upper and lower areas of the lung. Blood and interstitial fluid tend to gravitate downhill, increasing the fluid content in the lower areas at the expense of air space. Fourth, if a regulator is poorly adjusted, as many are, repeated strong negative pressure inhalations cause some interstitial edema, again displacing air. Fifth and finally, exhalation markedly reduces the caliber of the small airways. If an ascending diver exhales to residual volume, some or all of these factors will combine to narrow his airways and restrict air venting. That alone might suffice to rupture weak alveoli. But one can readily imagine that certain small airways might close completely. In fact, respiratory physiologists tell us that they do. And even mild exhalation might close an airway already compromised by a scar or cyst or tumor, or one partly blocked by an inflammatory process. Examples of the latter would be an active infection or its residuals; asthma; and chemical irritation as by cigarettes. All can produce edema, mucus, and bronchial spasm.

Certainly, breath-holding embolises the panicked diver, but it is exhaling that embolises the conscientious student who obeys his instructor implicitly. The instructor merely wants him to avoid breath-holding, but to the student, exhaling means reducing his chest volume to force air out. The more demanding the instructor and the more impressionable the student, the closer his lungs get to residual volume. The problem is really one of semantics. To solve it, we must stop the widespread practice of commanding students to exhale during air-venting ascents, or else redefine the term for them. Exhalation under such conditions is not natural, and they won't do it if we don't insist upon it. We must teach them to relax and leave their lungs at normal resting volume (FRC) and allow air to vent of its own accord. In view of the factors operating to reduce the diver's FRC, it might be better yet to advise expanding the lungs to some larger volume still well below total lung capacity.

A non-breathing, air-venting ascent need be no more hazardous than a normal breathing ascent. This is illustrated by a conceptual comparison of the two methods. In both cases the diver at depth has in his lungs high pressure air which must escape as he rises. But in the breathing ascent he periodically introduces still more air, and the total amount to be vented becomes much greater. Thus, if anything, the normal breather should be at greater risk. The only mechanically protective features of the breathing ascent which I can discern are that it tends to prevent breath-holding, and to keep lung volume within a safe range. If we can train the diver to do the same in a non-breathing, air-venting ascent, we will have exorcised its demons.

And we can. Methods have been developed for teaching the technique with great safety. Some instructors start in very shallow water and gradually increase the depth. Others prefer a sloping ascent up the bottom of a pool. The student may keep his regulator in his mouth for the security of a ready air supply. In any case, the keys are simple explanation, non-scare approach, and gradual progression. Skill and confidence will reward practice.

FREE ASCENT AND SUBMARINE ESCAPE TRAINING AT THE SUBMARINE ESCAPE TANK - NEW LONDON, CONNECTICUT

C. W. Shilling, M. D.

I was the Officer-in-Charge of the submarine escape training tank for several years during World War II, during which time we had 28,626 18-feet escapes, 21,661 50-feet, and 3,125 100-feet, for a total of 53,412 escapes, with not a single fatality and no cases needing recompression. True, these were not free escapes, they were training ascents using the submarine escape appliance or Momsen Lung.

From the time of the commissioning of the tank at New London in the thirties through the calendar year 1957, there were 193,004 training escapes using either the submarine escape appliance or the Steinke hood, with no fatality.

In the 1950's free escape training was undertaken and during the period of 1950 through 1960 there were 17,583 free escapes; they were categorized in four different categories as follows:

FA - free ascent without escape apparatus
FA(S) - free ascent without escape apparatus during SCUBA "ditch and don" maneuver
BA - buoyant ascent with life jacket apparatus
FBA - free breathing buoyant ascent (Steinke hood)

During this period there were three deaths, as outlined below, and 13 hood accidents, some requiring recompression. The fatality rate was .00017 and the morbidity rate .00074. The details of these were as follows:

Free Ascent (FA) without escape apparatus:

2 deaths - 4 cases cerebral air embolism

Free Ascent - FA(S)

0 death - 2 mediastinal emphysema
1 subcutaneous emphysema

Buoyant Ascent (BA)

1 death - 4 cerebral air embolism

1 syncope
1 subcutaneous emphysema

Total of 17,583 "Free" Escapes

Fatality rate: .00017
Morbidity rate: .00074

Statistics are also available for the five-year period 1961-1966 and are as follows:

Total of 40,913 Escapes - No Fatalities

BA - 7 cases - cerebral air embolism
1 case - pneumothorax

FBA - 4 cases - cerebral air embolism
2 cases - pneumothorax
1 case - mediastinal emphysema

Fatality rate: 0
Morbidity rate: .00036

EMERGENCY ASCENTS

Glen H. Egstrom, Ph.D.
UCLA Performance Physiology Laboratory

Ascents following the breathing of a compressed gas have been a major subject in every basic, advanced and instructor's course since the inception of diving instruction. As a result of whatever information was given, literally millions of safe ascents have been made by the divers involved in the programs. All concerned have accepted the fact that overpressure of the lung on ascent can result in damage which might become life threatening. As the sport has become more sophisticated we have seen a greater attention to the details and possible consequences of inappropriate behavior under nearly all conditions of participation with the gear. It is not at all uncommon to recognize that the more one knows about something, the more that person recognizes the enormity of the remaining unknowns. The more we learn about ascents, the more complicated are the answers to questions about ascents. Today I believe we are somewhat victimized by knowing a great deal and trying to provide ultimate protection in an area where the mechanically perfect solution will always be subject to the variables of human behavior.

In my understanding of the problem I must say that I cannot foresee any solution to the problem of ascending after breathing a compressed gas which will be completely satisfactory if our goal is ultimate protection. In any systematic attempt to reach "the" solution we will be faced with the knowledge that it will not provide for all eventualities. We will be forced to consider "trade-offs" which will hopefully put the risk-benefit ratio into an acceptable framework. At this point I am forced to point out that, to my knowledge, there have been no evaluations, statistical or logical, which have developed an accident rate for any of the emergency procedures in our sport. We are told of "increases" in incidence without any information pertaining to the level of incidence for activity. Our recent exercise in legislation has shown us the dangers of using only "failure" data in assessing risk.

I would submit that our practice of accepting or rejecting a course of action in emergency procedures in general should be based upon an objective assessment of risk vs benefit based upon actuarial data or, lacking such data at least look at the number of known problems against the background of estimates of participation based upon data such as certifications, Skin Diver projections, or other reasonable data base.

The following positions regarding this problem should be recognized as comparative and not definitive. I do not believe sufficient data has been accumulated to take a complete position.

Ascents can be identified as normal, in which case the diver is required to exhale and ascend at a rate which will not cause a pressure differential great enough to cause damage, or abnormal, in which the basic constraints are the same. It would appear that our concern should be directed at maintaining a safe pressure gradient regardless of any procedural choices. How we maintain this "safe" gradient under our selected procedural variations becomes an important issue.

These procedural variations each have some rather apparent strengths and weaknesses.

"Normal" ascent - This practice pre-supposes that no gas trapping circumstances are present and that the rate of ascent is compatible with the exhalation phase so that a minimal pressure differential is present.

1. We have no requirement to assure that even beginners are checked for the absence of gas trapping defects in their airways.
2. There is little training in the matter of safe ascent rate. Admonitions such as "don't ascend faster than the small bubbles" are given with little reinforcement.
3. The checks to insure that divers "always exhale while ascending" are apparently effective. The overwhelming majority of divers look up, exhale and ascend slowly in a safe manner.

"Abnormal" ascent - This practice is undertaken in circumstances where an intervening variable resulting in stress enters the picture. Low tank pressure, equipment malfunction, loss of buddy contact, concern for personal safety, etc. are a few examples.

1. The risk appears to stem from a loss of self-control resulting in a too rapid ascent rate. The crux of the problem appears to be the development of enough self-control and relaxation to insure that the diver will not permit a significant pressure gradient to develop during the resolution of the problem.
2. Any technique which is used will ultimately depend upon

self-control and an effective level of training.

3. What we should first address ourselves to is the question of teaching <u>safe ascents</u>, whether normal or abnormal. If venting is the problem we must teach them to vent effectively; if ascent rate is the problem we must train for slower ascent rates.

4. All alternative emergency procedures must be standardized, overlearned and reinforced. I suspect that much of the stress involved in using any of the emergency procedures is a result of a lack of confidence in the diver's ability to perform adequately.

<u>Questions</u>

1. Do we have a data base to deal with the problem objectively?

2. Are there standardized procedures for:

   a. low tank pressure and related problems?
   b. buddy breathing?
   c. use of the auxiliary second stage?

3. Will either the single or dual second stage system operate effectively under all conditions?

   a) deep water
   b) low tank pressure
   c) two heavy breathers
   d) cold water

4. Does the suggested procedure create more problems than it solves?

My investigations strongly suggest that the answer to all of the above is No! Thus it appears that the evaluation of any procedure should be responsive to the question "Would the procedure be safe and effective if it were overlearned and reinforced to the point where stress was minimized?"

THE HAZARDS OF SPORT DIVING
FREE ASCENT TRAINING

Martin J. Nemiroff and John W. Dircks

INTRODUCTION: In the diving community there are probably few issues as controversial as Free Ascent training. Interchangeable terminology has contributed confusion to the controversy. In several articles in the 1972 and 1973 Undersea Journal, Mike Clark and Jean Simon define the basic differences between free ascent, buoyant ascent, free swimming ascent, emergency swimming ascent, and controled emergency ascent. Others have described assisted ascent, controlled breathing ascent, and buddy breathing ascent.

For the sake of clarity and ease we will use the term free ascent in this paper to mean any underwater maneuver to rise to the surface in one breath, taken under pressure, whether it is exhaled at depths or while ascending to the surface. In addition this occurs whether or not the diver is ascending to the surface on his or her own power, internal buoyancy, or utilizing an external flotation device.

In essence, we are concerned with those maneuvers that decompress the diver over a brief period of time and in one breath, both of which depend on a judgment of how fast to exhale and on the physiological integrity of the lungs to empty all air equally well.

In the bibliography are articles in which the pros and cons of training free ascents are discussed. It is not within the scope of this paper to review these but I would like to list some of the points that have been made (NAUI News, August - September 1973).

PROS:

It builds confidence
Prevents panic when confidence is needed
Even basic students need it
Safer modifications than the Navy classic ascent are available
Most instructors report little problem with it
BSAC estimates 15,000 ascents with no incidents
Free ascent practiced in France by all groups

CONS:

U. S. Navy says if no chamber available it should not be done

Potentially dangerous
Should be taught in advanced diving only
Can be simulated in a horizontal pool
The emergency need for free ascent is overemphasized
Drills are never the same as emergencies
Recent deaths during practice have been reported
Australian and Royal Navy both say <u>no</u> without chamber
Incidents are going unrecognized by instructors

In this paper we will present four cases of free ascent injuries seen during the past year at the University of Michigan Medical Center Hospitals.

<u>CASE 1</u>: A 15-year-old male student was scuba diving in a lake under the supervision of a certified instructor. During a training session at 10 feet of depth he rose to the surface suddenly. He experienced a frontol headache, and 5 minutes later had a sharp aching chest pain, radiating to the neck. He did not inform the instructor. He sought aid at a nearby clinic, where the diagnosis was pulmonary barotrauma, subcutaneous emphysema, and mediastinal emphysema. He was discharged and told to return one week later for a follow-up chest X-ray. A subsequent interview with the patient revealed he had made a free ascent without realizing the risks and consequences of his accident. His instructor was notified one week later. This case illustrates how these accidents may occur without the knowledge of the instructor and with inadequate treatment and follow-up. This case would seem to demonstrate well that shallow depths do not protect one from pulmonary barotrauma on ascent.

<u>CASE 2</u>: An 18-year-old male was diving at Lake Erie in 20 feet of water when his new equipment apparently malfunctioned. He ascended rapidly to the surface, exhaling all the way. At the surface he experienced mild substernal chest pain and shortness of breath. This was associated with lightheadedness, general weakness, and vertigo. The patient arrived by helicopter 6 hours after the incident, still complaining of substernal chest pain on deep inspiration. The vertigo, weakness, and nausea had cleared while breathing oxygen during the flight. Past history revealed the diver was experienced and certified, and had made a previous rapid ascent 6 months prior. The previous ascent resulted in left-sided chest pain that required intramuscular pain medication 6 hours later! The diagnosis after appropriate examination and chest X-ray was pulmonary barotrauma, with no evidence of neurological damage. This case illustrated repeated free ascent morbidity in a trained certified diver.

<u>CASE 3</u>: A 27-year-old diver of 8 years' experience, including two certifications and experience in underwater photography and welding, was taking an advanced course. He attempted an assisted (buddy breathing) emergency ascent from 50 feet in full gear but with the air turned

off. He ascended faster than his buddy, became frightened, and swam quickly towards the surface. His instructor grabbed his flipper and slowed the ascent, forcing him to exhale. On the surface he had moderately severe chest pain and then developed a headache. He rested on the shore that afternoon but performed a night dive, and then two complete 50-foot dives the next day. Five days later he was seen in the emergency department with residual chest pain and headache.

Physical examination, chest X-ray, and EKG were all normal. It is difficult not to believe that the patient had pulmonary barotrauma and even air embolism with that ascent. This diver was a 1½-pack-per-day smoker. This case suggests that even experienced divers can panic and ascend rapidly, holding their breaths. The seriousness of the incident was not realized by the diver or the diving instructor.

CASE 4: The last case is that of a 27-year-old certified diver practicing free ascents in a lake, starting at a depth of 40 feet. His instructors (one at the bottom and the other at the surface) noted correct ascent rates and exhalation all the way. The patient surfaced from the first ascent after a bottom time of 3 minutes and swam 20 feet. He suddenly convulsed and became rigid in the water. After an ambulance ride of one and a half hours, he arrived at our hyperbaric facility. He was comatose, convulsing, vomiting, and his pupils were fixed and dilated. Blood pressure was unobtainable and the peripheral pulses were no longer palpable. He was pressurized to 165 feet of seawater immediately and his pulses returned. He was improved physiologically, with stable vital signs, after the administration of fluids, corticosteroids, and diazepam (Valium). An extended U.S. Navy Table 6A had to be terminated 30 minutes early after the patient developed subcutaneous emphysema, bilateral pneumothoraxes, and cardiovascular instability. Resuscitation was successful and the patient was left with aphasia, a left hemiparesis, and a clouded mental state. After a two-month hospitalization with intensive physical therapy, the patient had a normal sensorium, a near-normal gait, and an intention tremor. The final diagnosis was pulmonary barotrauma, bilateral pneumothoraxes, subcutaneous and mediastinal emphysema, and cerebral air embolism!

In retrospect this diver had mild asthma, was a two-pack-per-day smoker, and had frequent bronchitis and hay fever. In addition he had a previous history of hypoglycemia.

DISCUSSION: In evaluating the hazards of free ascent, answers to several basic questions can be inferred from the literature. Among these are: what are the chances of a complication from free ascent, and what are they; is it possible to screen candidates; are there procedural differences to reduce the hazards; and finally, what are the modes of therapy necessary to save the diver?

A U.S. Navy study of submarine escape procedure from 1928-1957 shows there were 62 accidents. These maneuvers were carried out in

18, 50, and 100 foot depths. This study also included 17 recompression chamber casualties; of these 17, only one is known to have held his breath and none died, but 10 had air emboli for unknown reasons.

More frightening statistics are reported in a prospective Swedish study of submarine personnel age 19-20 undergoing submarine escape training in 5-65 foot depths. These recruits were screened neurologically and by electroencephalogram (EEG) before and after ascents. Of the 112 subjects, 14 had EEG changes felt by the authors to suggest air emboli. Of these 14, 9 had focal or generalized neurological deficits. Four of these 14 had both this "evidence" of air embolism and lung rupture with pulmonary barotrauma. In this study the incidence of pulmonary barotrauma and/or air embolism was 3.5%. Of more disturbing interest is that all barotrauma was associated with diagnosable air emboli. How many lung ruptures seen in divers also are associated with occult emboli?

A U.S. Navy report released in 1964 revealed 44 air embolism casualties (0.018%) and 8 fatalities (0.003%) for 250,000 free ascents, the 8/44 fatality to casualty ratio being 18.2%. The incident of barotrauma without known air embolism was 22/250,000 or 0.009%. However, a study at the New London Tank revealed an incidence of barotrauma with free ascent of 16/16,500 or 0.1%, with 2 fatalities (0.012%), and a fatality to casualty ratio of 12.5%. Both studies were done with a recompression chamber available at the dive site.

The U.S. Navy reported 7 deaths over a 15-year period of scuba training. This was with careful scrutiny and supervision of the divers and with a recompression chamber immediately available. A Pearl Harbor report documented 7 episodes of air embolism, most of which occurred during buoyant ascent. At post mortem these previously "healthy" divers had the following abnormalities: 2 had scars on their lungs, 1 had a bleb on his chest X-ray, and 4 had mucous plugs secondary to bronchitis not previously suspected.

In England, Miles (1962) reported 25 accidents for 50,000 training ascents from 90 feet in a training tank. Nineteen of these 25 had cerebral air embolism, for an incidence of 76% of the accidents.

Civilian studies are difficult to assess since during most civilian autopsies no specific precautions are taken to document air embolism as the etiology of death. In many cases autopsies are not even attempted and death certificates record "drowning" as the cause of death for a scuba diving mortality! However, many authors feel that air embolism may play a major role since equipment malfunctions are rare and no other cause can be found. There are no good civilian studies on the incidence of air embolism in sport divers performing free ascent, but these diving fatalities may reflect the hazards of air embolism in other than emergency ascents. As can be inferred from the U.S. Navy casualties in supposedly well-screened recruits, it is not easy to detect who will develop barotrauma with free ascent.

The conditions that are contraindicated in free ascent include all that prevent free ingress and egress of air from the cavities in the body, and especially the lungs. These include: chronic and acute bronchitis, asthma, emphysema, positive skin tests for tuberculin or histoplasmin, benign and malignant chest tumors, congenital cysts and bullae of the lungs, granulomatous disease of the chest (including tuberculosis and fungal disease) and calcified scars in the lung, especially lymph nodes seen at the bifurcation of the major bronchi. Even such "mild problems" as smoking associated with mucous plugs may well contraindicate free ascent.

In 1959, Liebow reviewed the history and pathology of cases of air emboli seen in submarine escape training exercises from 50 feet. At autopsy one had a broncholith in the lung and the other bullous emphysema. He demonstrated on lung sections how nicely bullae can be occluded in emphysematous lungs as pressure is increased with ascents. From his discussion and pictures it is easy to see how "occult lesions" could predispose to air embolism.

In our experience examining candidates for scuba training at the University of Michigan and casualties treated in our hyperbaric chambers, we are confronted frequently with people who wish to scuba or those who are scuba diving with a contraindicated physical defect. Though we are sensitive to this problem, hurried and pressured family physicians might not be as vigorous in their screening of candidates as the Navy. One would therefore expect an even higher incidence of air embolism with free ascent than the Navy studies suggest. It is unfortunate that at this time we have no good, inexpensive, readily available tests to rule out airway disease. Chest X-ray, pulmonary function tests, lung scans, and other special expiratory films may screen candidates for "air-trapping" but they by no means rule this entity out.

Recompression therapy is still the major hope of salvaging a patient of a scuba diving free ascent accident. Some authors feel even a 2-minute delay before recompression portends a bad prognosis. In our experience and that of others, the usual 1 - 3 hours needed to reach a hyperbaric facility following air embolism has indeed caused fatalities or significant neurological residual defects. In Navy studies of those air embolism cases which survived, recompression was begun on an average within 3 minutes in 23 cases of the 44 casualties. In 7 cases it was begun in 6-10 minutes and in two other cases from 1½ - 2 hours; four patients survived without recompression. Of eight fatalities, two were recompressed in 2 minutes, one after 30 minutes, two after 5-6 minutes, and three were not recompressed. The Navy concluded from these statistics that survival depends on availability of a recompression chamber. Obviously such a chamber is not within minutes of the sport diver trainee. Though other modalities of treatment are used (oxygen, steroids, anticonvulsants, etc.), the only definitive treatment to prevent severe and permanent neurological damage is the recompression chamber.

PROCEDURES: The question of what procedure or modification of present procedure would reduce morbidity and mortality of free ascents has been raised; the following comments relate to this question.

1. Better screening? At present there are no good tests readily available and inexpensive enough for mass screening for airway disease.

2. Studies have shown that multiple ascents seem to predispose to accidents; repeated practice could perhaps be eliminated.

3. Shallow depths do not protect a diver and in fact may be more dangerous; they also give a false sense of security. Perhaps practicing free ascents from 100 to 50 feet might be safer.

4. Inflated buoyancy compensators are no protection.

5. The rule about rising no faster than one's smallest bubbles may not be a helpful guideline in murky water.

6. Perhaps the single breath ascent should be replaced by buddy breathing ascents; the obvious drawback to this is evident from Case 3.

7. Know the location of the nearest recompression facility and practice ascents nearby.

8. Practice horizontal free ascents in a pool.

SUMMARY: As can be seen from our review of four cases and a review of the literature, free ascent does carry considerable risk as a training maneuver. The significant but probably not totally known incidence of air embolism, the lack of good screening rests for physical defect, the high morbidity-mortality ratio even with rapid decompression, and the general difficulty of reaching recompression facilities rapidly make this maneuver even more hazardous for the average sport diver.

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THE EMERGENCY ASCENT DILEMMA

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INTRODUCTION: During the past year there has been an increasing demand on the part of scuba diving instructors and other diving authorities for a re-evaluation of emergency ascent procedures in sport scuba diving. Many diving medical authorities challenge the inclusion of open water free ascent or emergency controlled swimming ascent training in basic and advanced sport diving courses. In essence, they feel that the potential risk of lung barotrauma is greater than the benefits derived by the student in such exercises. On the other hand, many scuba instructors feel that the controlled emergency swimming ascent is a vital part of scuba training and suggest that failure to practice such procedures during open water training is in direct violation of good diver training practices. Some authorities suggest that open water practice of emergency ascents is absolutely necessary to develop the student's "confidence" in resolving potential life or death emergency situations.

Another emergency ascent procedure is the "buddy-breathing" ascent. This procedure has been considered as the basic method of resolving underwater emergencies related to air supply depletion or failure for years. Most instructors religiously include a considerable amount of buddy-breathing practice in pool and open water training. Now, buddy-breathing procedures in emergency ascent must also be re-evaluated. In some incidences unsuccessful attempts at buddy-breathing ascents may have contributed to double drowning fatalities. New techniques of buoyancy control buddy-breathing ascents are becoming increasingly complex.

TERMINOLOGY: Numerous terms and definitions have been applied to various emergency ascent procedures throughout the relatively short history of sport scuba diving. Frequently, the terminology is not well-defined in the literature and misuse or misunderstanding of the various terms has led to confusion and misinterpretation. Several authors, both in books and diving agency newsletters, have relatively comprehensive lists of related terms and definitions. Specific recognition is given to the articles titled "Free Ascents" by Jon Hardy ((NAUI News, July 1971) and its expanded version presented at the Third International Conference on Underwater Education and "Emergency Ascents: Which Way Up?" by Reg Vallintine (NAUI News, August/September 1973). For purposes of this text the following terms and definitions will apply:

Emergency ascent - any form of ascent undertaken as a result of an emergency. In accord with Lee (1971), the definition refers to the diver's situation and does not specify the origins of the emergency, be they psychological or real, nor the specific mode or method of ascent.

Free ascent (sport diver) - an ascent undertaken in an emergency without the assistance of a buddy diver, auxiliary breathing apparatus, or buoyancy equipment. The diver swims to the surface under his own power. This definition implies that no breathing supply is available to the diver and that continuous or nearly continuous exhalation is maintained throughout the ascent to prevent lung barotrauma. Since I am discusssing sport diving, I am including only the inferred definition related to the sport scuba diving community and not necessarily that associated with naval submarine escape training. Some authorities recognize "controlled exhalation to provide positive buoyancy" as fundamental to defining a free ascent. From the standpoint of traditional usage in sport diving, I suggest that the "blow and go" with little or no consideration of controlled exhalation techniques is more accepted.

Free ascent (U.S. Navy) - an emergency ascent procedure accomplished by floating to the surface by means of natural buoyancy (no buoyancy aids or equipment used). Air is exhaled continuously at a rate such that buoyancy is maintained, but the exhalation is sufficient to prevent over-expansion of the lungs (U.S. Navy, 1963, p. 134).

Positive buoyancy ascent - an emergency ascent procedure utilizing the aid of buoyancy equipment. Most frequently this implies the use of a buoyancy vest, inflatable lifejacket, back-mounted buoyancy unit (i.e., At-Pac or equivalent), variable-volume suit, or similar devices to provide significant positive buoyancy. Some authors recognize the buoyancy factor of the diver's wet suit or diving dress, once the weight belt is released, as applicable under this definition. I would prefer to think more in terms of specific buoyancy equipment. This term also implies that once the diver attains the positive buoyancy mode, he can and/or does no longer control his ascent. He is carried to the surface with a buoyancy factor consistent with the capacity of his buoyancy device, sometimes exceeding 45 pounds of upward lift or buoyancy.

Buoyancy assisted ascent - a controlled ascent procedure utilizing buoyancy aids. Most frequently this implies the use of a buoyancy vest, inflatable life jacket, back-mounted buoyancy unit, variable-volume suit, or similar devices to provide sufficient buoyancy. Unlike the positive buoyancy ascent, the diver regulates the amount of buoyancy provided by his buoyancy unit by manually admitting or expelling gas from the system. The ultimate objective of this method is to maintain an acceptable rate of ascent (ideally not exceeding 60 ft/min). It is also implied that the diver has no breathing gas for use during ascent.

Controlled emergency swimming ascent - a controlled swimming ascent without benefit of an air supply in which the diver swims to the surface under his own power (without the use of positive buoyancy) while exhaling continuously. He maintains an acceptable rate of ascent (ideally, not exceeding 60 ft/min) and exhales throughout the ascent.

Buddy-breathing emergency ascent - a controlled emergency swimming ascent in which two divers share air from a single scuba. This implies that each diver is exhaling appropriately to prevent pulmonary barotrauma and that an acceptable rate of ascent (ideally, not exceeding 60 ft/min) is maintained throughout the ascent. Also, it is implied that only a single mouthpiece is used (excludes the "octopus" unit).

Auxiliary breathing apparatus ascent - a controlled emergency swimming ascent in which a diver may share his buddy's air supply by use of an auxiliary mouthpiece ("octopus" unit), breathes air from his compressed air buoyancy vest, or uses a small auxiliary scuba ("pony" unit). Naturally, a normal scuba diving type of ascent is possible in this case.

Some divers combine two modes of emergency ascent. For example, the buoyancy assisted and buddy breathing emergency ascents may be combined. It is not my intent to further confuse the issue with the above terms and definitions. I simply wish to provide a common basis for discussion. Let me assure you that all of these types of emergency ascents or modifications thereof are being taught in scuba classes throughout the United States and the world today.

THE EMERGENCY ASCENT CONTROVERSY

Since the earliest days of sport scuba diving, there appears to have been considerable disagreement or misunderstanding within the diving community regarding emergency ascent procedures and practical training in emergency ascent. Certainly everyone has agreed that there must be some form(s) of emergency ascent procedures for scuba divers and that this (these) procedure(s) must be included in basic scuba diver training. The controversy appears to encompass several factors, namely, (1) what procedure(s) shall be considered proper for sport divers, (2) how shall these procedures be taught, (3) at what phase of diver training shall they be included, (4) shall these procedures be practiced only in the pool, and (5) shall these procedures be practiced in open water.

Today, the major controversy appears to revolve primarily around the practice or open water training aspects of emergency ascent. The major concern is with those procedures which involved ascending to the surface without the benefit of a shared or auxiliary air supply. The U.S. Navy Diving Manual (U.S. Navy, 1963, p.134) makes the following statement:

> "Free ascent, as this procedure is termed, is difficult for the untrained individual and must never be taught

> at facilities which do not have the proper equipment and personnel to provide adequate supervision of ascents and treatment of accidents that may result. The immediate presence of a recompression chamber is absolutely necessary to carry out any free ascent training."

Other publications from official Navy sources, by Navy associated personnel (past and present), and by some civilian diving authorities (primarily physicians) have included similar statements. These statements and the traditional Navy definition of "free ascent" for scuba divers have been among the primary factors in the development of present day attitudes toward the negative aspect of emergency ascent training. Admittedly, the traditional Navy free ascent can be considered a relatively hazardous procedure, especially for the novice diver.

The sport diving community's emphasis and philosophy on emergency ascent training is documented by numerous authors in association newsletters and journals. I have selected two noteworthy items which, in my opinion, played a significant role in establishing the present attitudes towards emergency ascent training within the sport diving community. Egstrom and Bachrach (1971) state:

> "Another breathing problem, a serious one in divers, is the risk of air embolism. A diver in panic who is ascending holding his breath is in marked danger of embolizing. We believe that one of the important skills to be developed in diving courses is the effective use of controlled emergency ascent so that the diver in trouble exhales properly. In a panic situation it is likely that the inexperienced diver will hold his breath, with serious consequences."

Icorn (1972) states:

> "Emergency ascent training is a necessary and vital skill required in all basic training to provide the means in the event of a failure for a diver to safely regain the surface.
>
> This type of training can effectively and safely be implemented thru the basic course directly into open-water training with safe, simple, progressive water skill."

The U.S. Navy recognizes and trains its scuba divers in positive buoyancy emergency ascent procedures. The U.S. Navy (1973) states, "the principal function (referring to the scuba diver's life preserver or buoyancy vest) is to assist a diver in rising to the surface and to maintain him on the surface in a head-up position." In the U.S. Navy (1973, p. 5-37) specific instructions for emergency ascent include, "After dropping all heavy objects and the weight belt, activate the life preserver and surface immediately." The new U.S. Navy Diving Manual does not appear to place the same hazard emphasis on the positive buoyancy ascent as previous editions. The Manual (1970) states, "Use positive-buoyancy ascent only to resolve a life-or-death situation, and no other. Otherwise swim to the surface."

I might add that safety precautions are rigorous and, to my knowledge, recompression chambers are required at the site of all U.S. Navy emergency ascent training. I will discuss emerging problems relative to positive-buoyancy ascents in the sport diving community later.

The buddy breathing emergency ascent procedure has been a basic or fundamental method of resolving underwater emergencies related to air supply depletion or failure since the earliest days of sport scuba diver training. Many instructors religiously include a considerable amount of buddy breathing practice in both pool and open-water training. They emphasize the buddy breathing emergency ascent as an open-water training exercise for basic scuba diving students. This emergency ascent is certainly not without several potentially serious problems. First, the conditions of practice are generally extremely controlled relative to environmental, physical and emotional stress. In other words, "ideal." It is my opinion and experience that buddy breathing emergency ascents seldom work for divers who have not trained and continuously practiced together. Under "real" conditions of emotional stress (including confusion and near-panic), cold-dark water, fatigue, leaking masks, buoyancy control problems, etc., the technique frequently fails. In other words, these are the real conditions which may confront two divers, experienced or inexperienced, in a lake or ocean environment. Instructors may incorporate controlled stress factors such as fatigue into buddy breathing training, but is this enough?

Also, the analysis of some scuba diving accident reports suggests that some unsuccessful attempts at buddy breathing ascents have led to double drownings. This is a very real and certain problem which must be recognized by all students and instructors.

Based on interviews with a limited number of divers who have faced "actual" situations in which buddy breathing ascents were indicated, I have concluded that many, if not most, attempted buddy breathing emergency ascents (not simulated) end in a "free" type of ascent for one or both divers. Certainly, I acknowledge that there have been some successful buddy breathing ascents, but the percentage of success is probably relatively small.

Shea (San Diego Evening Tribune, December 21, 1971), as quoted in an article by Monday (1972), referred to the buddy breathing ascent as possibly being the "wrong method" of emergency ascent from shallow water dives. He said, "a free ascent to the surface immediately on discovering the loss of air now appears to be better" and, "As a general statement, for the general diver, the free ascent is probably the better way (in shallow water). Obviously under a kelp bed it would be necessary to use the buddy system - or a combination of both systems."

Now let us explore some of the more recent developments in methodology. Over the past few years there have been tremendous developments in the area of buoyancy compensation equipment and, in turn, what I will term as the "buoyancy compensation diving philosophy." This has added a new dimension to the emergency ascent. McKenney (1976) reports on 10 buoyancy compensator vests that provide 27 to 43 pounds of lift capacity; there are at least 16 additional units currently available. I am also aware of at least 9 backpack-mounted units of similar capacity. Although documented reference to positive buoyant ascent training in the sport diving community with specific methodology appears to be limited, I am aware of such procedures which are included in many basic diving courses. I have observed divers accelerating towards the surface with fully inflated buoyancy units in open water classes being conducted at a northern Ohio quarry. The ascents were initiated in depths of approximately 40 feet. Similar reports come from observers in other parts of the country. The precedent for this type of ascent has been well established in Navy training under strictly controlled and specified conditions but has only quite recently emerged to specific open water practice levels in the American sport diving community. I must point out that instructions for positive buoyancy ascents are given to British divers in The British Sub Aqua Club Diving Manual (Zanelli, 1972). It may well be that positive buoyancy ascent procedures utilizing buoyancy units are about to emerge as a "routine" procedure in the American diving community. Practice of this procedure is extremely hazardous and, in my opinion, should be discouraged.

The increased emphasis on buoyancy compensation diving has also influenced the buddy breathing emergency ascent methodology. With the increased emphasis on buoyancy compensation equipment there appears to be a lesser emphasis on "proper weighting" of divers. Although my observations are subjective, I concluded that more than 40 percent of the divers that I observed at one northern quarry on several occasions were, in fact, overweighted. Consequently, in my opinion, excessive compensation was required to offset negative buoyancy at depth. This air must be vented from the compensator in order to maintain an acceptable rate of ascent. In the event of an emergency ascent using buddy breathing techniques, each diver must cope with the added complication of excessive expanding air and manually venting the buoyancy compensator. The positive buoyancy assist might be considered a benefit by some and a detriment by others.

The complexity of methodology is further illustrated by the discussion of an emergency buddy breathing ascent procedure recommended in a recently released sport diving manual (Jeppesen Sanderson Inc., 1975). The following description is quoted from text:

> "The 'donor' holds the regulator in the right hand and holds the vest inflator with the left hand. The 'needer' grabs onto the 'donor's' right hand and regulator, and holds the vest with the left hand. One buddy inhales from the regulator two times, while the other slowly exhales into the vest inflator. The buddy team continues this procedure until both vests are adequately inflated."

I believe it has already been established that buddy breathing is difficult, if not virtually impossible, under many "real" (not simulated) conditions. These added inflation procedures only complicate an already marginal procedure.

The use of auxiliary breathing systems such as "pony bottles" (a small separate scuba unit) or "octopus rigs" (an auxiliary second stage assembly) appears to be an exceptionally good alternative to conventional buddy breathing and other forms of emergency ascent. The use of such systems is well documented in literature and highly emphasized by specialty groups such as cave divers. Most manufacturers even sell a regulator with two second-stage assemblies or at least provide extra low-pressure ports on regulators to facilitate attachment of auxiliary second stages. Four specific areas of concern must be noted. First, the general diving public has not widely accepted the "octopus rig"; at least in my personal counts at northern diving areas only 6 out of 184 divers observed had any form of auxiliary breathing device (all octopus rigs).

Second, the sport diving industry has, to my knowledge, not produced a compact, small volume scuba specifically designed for emergency ascent. It seems logical that with modern day technology a compact emergency scuba could be developed and marketed at a reasonable cost. This unit could be attached to the diver's harness, scuba cylinder, or buoyancy vest in such a fashion that it would be readily available in an emergency and not be excessively encumbering during normal diving.

Third, several instructors, authors, and manufacturers have elaborated on the use of the buoyancy vest air supply for auxiliary or emergency breathing purposes. This procedure appears to have "not caught on" in the United States. I have found this to be an awkward procedure even under the best and most controlled conditions. The continued change in buoyancy (from ascent) combined with the breathing of air from a mouth unit not specifically designed to also accommodate exhalation induces specific hazards. I can not endorse this procedure until equipment modifications have been made, specific training procedures have been developed, and the procedure has been adequately and objectively tested and proven relatively safe.

Fourth, the diving instruction community has not clearly defined the proper procedures for training and use of the auxiliary mouthpiece. Also, the position of the auxiliary second stage on the diver has not been standardized; this could lead to confusion in the actual use of the equipment in an emergency. Under cold water diving conditions the increased air flow requirements <u>might</u> initiate regulator first stage malfunction as a result of "freeze up." Recent research further suggests that many scuba regulator second stages will not provide adequate air flow to support two divers breathing under stress conditions in deep water.

Let us now narrow the discussion to the real issues facing the diving community today. First, the key issue seems to be the practice of certain types of emergency ascents in open water by sport diving students. Everyone seems to agree that an emergency ascent procedure must be included in the student's training. Most support the practice of emergency ascents in a swimming pool environment. Many feel that open-water practice of emergency ascents is vital to the safety and well-being of the diver. On the other hand, some authorities, especially medical personnel, openly oppose the practice of controlled emergency swimming ascents or similar procedures in open water. They feel that the potential risk of lung barotrauma and the lack of immediately available recompression facilities outweigh the potential benefits derived by the student from open-water practice. One submarine medicine authority has apparently stated that, "the practice of free ascents in open water is like practicing bleeding." He further reflects on the actions of a reasonable and prudent person with this brief analogy (based on my recollection from a lecture):

> "Upon acquiring a third floor room in an old wood frame hotel, the traveler concludes that there is certainly a greater than normal risk of fire. In fact, three recent fires have been documented. Consequently, he sets out to develop an emergency plan of action in the event of a fire by assessing the various means of escape. The small hotel swimming pool is located below the window to his room. If the traveler is a reasonable and prudent individual, he will look at the pool and say to himself, 'as a last resort I am confident that I can safely leap from my window into that pool.' A less reasonable and prudent individual will make a practice jump."

Needless to say, the sport diver making practice free ascents is the one making practice jumps above.

Second, many diving instructors have indicated to me that the fear of potential lung barotrauma is without foundation. They are unaware of any serious injuries in the sport diving community directly linked to emergency ascent training. I too am keenly aware of the limited number of cases reported in the literature readily available to the sport diving community. Let me assure you that pulmonary barotrauma is a real and documented occurrence in sport diving emergency ascent training. Nemiroff and Dircks (1976) have documented several cases of emergency ascent-related pulmonary barotrauma seen at a major midwestern medical center in an 18-month period.

Third, is the buddy breathing emergency ascent procedure the answer to emergency ascent training: Some elements of the diving community have already publically voiced dissatisfaction with the buddy breathing procedure. Assessment of the realities of actual stress situation buddy breathing, as subjective as they may be, seem to indicate that in most sport diving cases the "free" ascent is a more acceptable alternative than buddy breathing. Yet this procedure is religiously and vigorously emphasized in sport diver training today. Such emphasis, in my opinion, is instilling a high degree of overconfidence in basic scuba diving students that is inconsistent with the realities of actual diving. Furthermore, many instructors are using the buddy breathing emergency ascent procedure in their class because they feel "safer legally" than with the controlled emergency swimming ascent. Establishing any means of protection from potential lawsuit appears to overshadow personal preference, logic, and the psychological development of the student.

Last, but certainly not least, what is the future of positive buoyancy emergency ascent training in sport scuba diving? I feel that it is a situation that must be immediately addressed by the recognized authorities of the diving community. It is certainly a recognized and documented technique. Should sport divers practice this type of ascent? If so, how? Under what conditions? From what depth? Are risks significantly increased? What is the most desirable procedure? I feel we are in a "gray area" at this point.

EMERGENCY ASCENT METHODOLOGY

All authorities agree that scuba divers must learn techniques of emergency ascent. As previously indicated there are at least seven methods or techniques of emergency ascent commonly used within the diving community today. As a diver you must develop a behavioral response to a variety of situations with variables in emotional stress, buoyancy, assistance from another diver, physical condition (fatigue level), and equipment. The National Scuba Training Committee lists some 18 variables that must be considered when selecting the appropriate method of emergency ascent. These are:

1. Depth

2. Visibility
3. Distance from other diver or divers
4. Nature of activity being pursued (active swimming vs. stationary activity)
5. Focus of attention of other diver or divers
6. Available breathhold time
7. Individual stress level
8. Training level relative to emergency procedures of all divers concerned
9. Training recency relative to emergency procedures of all divers concerned
10. Diving experience of all divers concerned
11. Emergency experience of all divers concerned
12. Obstructions to ascent
13. Water movement
14. Buoyancy of all divers concerned
15. Available equipment of all divers concerned
16. Familiarization of involved divers with each other's skill and equipment
17. Apparent reason for air loss
18. Decompression requirements

Probably the most appropriate first step in emergency ascent is the response philosophy. The diver must be capable of selecting the best method or combination of methods to safely ascend. A behavioral pattern response to "out of air" might be as follows:

1) If the diver simply experiences a breathing resistance, he should check his pressure gauge, activate the low pressure warning device override (reserve valve), signal his buddy, and make a normal controlled ascent breathing reserve air.

2) If, upon activating the reserve (or checking the pressure gauge), no additional air is available, the diver may choose to start a controlled normal ascent and breathe "lightly." Even if the air cylinder appears empty at depth, the normal expansion of air during ascent, about .5 cf for every 33 fsw, will most likely be sufficient for a relatively normal ascent. Naturally the buddy should be signalled.

3) Now let us assume that the regulator has malfunctioned, thus not allowing any expanding air to pass to the diver, or the diver has started to "gasp" for air. If the diver attempts to inhale deeply and rapidly, there will not be sufficient air for a normal ascent. The diver must now progress to the next alternative(s). If the diver is wearing an auxiliary scuba (pony bottle) or if the buddy is immediately available with an auxiliary mouthpiece (octopus unit), then auxiliary breathing equipment is, under most conditions, desirable.

4) However, if auxiliary breathing equipment is not readily available and the distance to the surface is less than 75 fsw, the diver will probably choose the "controlled emergency swimming ascent." If he is at a depth greater than 75 fsw, then he will have to evaluate the situation and, possibly, choose a buddy breathing ascent.
Note: I selected the 75 fsw depth as a "decision" depth because most divers will have been able to accomplish a 75 fsw "simulated" controlled emergency swimming ascent in the pool. Some divers, particularly those with experience, may choose the swimming ascent from a deeper depth.

5) Now, let us assume that the diver is "heavy" or doesn't appear to be getting any place. At this point he may well choose the buoyancy assisted or positive buoyancy ascent. We are assuming that the good diver is maintaining near neutral buoyancy at depth. Consequently, some buoyancy will be realized shortly after initiation of the ascent. Venting of the vest or buoyancy compensator now becomes necessary. Another method of gaining buoyancy is to release the weight belt. The weight belt release appears to be "overlooked" since a number of scuba diving fatality victims are found on the bottom with their weight belts still in place. Finally, if the diver "questions" his chances to ascend to the surface using controlled swimming or the buoyancy assisted method, he may choose to go to a complete positive buoyancy ascent by activation of the air or CO_2 cylinders on his buoyancy vest. It should be noted that the buoyancy vest inflated directly from the scuba will be of little use at this point (to gain a full positive buoyancy ascent) since air is not available from the scuba. It should be further noted that some authorities advocate the exhalation of air (mandatory during an emergency ascent) directly into the buoyancy compensator through the oral inflator to gain a buoyancy assist.

6) If the diver's path to the surface is obstructed (cave, ice, kelp, etc.) or the depth is considerable, the buddy breathing emergency ascent may be the best alternative.
To summarize, the diver must make a decision as to the best ascent procedures, based on a number of variables. Hardy (1976) proposed the following sequence of selection:

1. Controlled emergency swimming ascent
2. Buoyant ascent
3. Buddy-breathing ascent

Hardy's paper emphasizes the necessity of the emergency ascent in the "real" world of diving; it is certainly a most realistic alternative to drowning.

The controlled emergency swimming ascent is fundamental to diving safety. In the "real" world of diving each and every individual must be prepared to make this type of emergency ascent. The following is one recommended procedure:

1) Assure yourself that there is no other safer or better way to resolve the situation.
2) If possible, signal your buddy of the intended ascent. However, under severe stress you will probably go directly to the surface with nearly total disregard for your buddy. Don't waste valuable seconds looking for a buddy if he is not immediately available.
3) Unless the breathing apparatus is entangled, the diver should not abandon it even though it may be useless. Do not waste valuable seconds!
4) Place one hand on your weight belt buckle so you can immediately release it if necessary. The diver need not initially drop his weights. Many instructors suggest that this could result in an uncontrolled ascent. However, realistically, the added rate of ascent from wet suit expansion is relatively minor.
5) Retain your mouthpiece, start exhaling, and kick firmly toward the surface. The head must be extended back to open the airway completely. This allows maximum opening of the throat area and a good overhead view.
6) Some instructors advocate injecting a small amount of air into the buoyancy compensator, just enough for a buoyancy "assist" and not an all-out positive buoyant ascent.
7) If there is air in your buoyancy compensator, prepare to vent the air in order to maintain a controlled ascent. Vent as needed! Ideally, the hand holding the vest-venting hose is slightly above the head to protect you from floating objects at the surface.
8) Exhale continuously! If no air is expelled, keep the airway open, since expanding air must be expelled eventually.
9) If you experience difficulty in swimming to the surface due to overweighting, drop the weight belt.
10) About 15 feet from the surface the diver can flare back (assume a more horizontal than vertical position) to slow ascent and float to the surface, in most cases.

In desperate emergency situations where the diver feels that he may lose consciousness or is extremely negative, it may become necessary to make a positive buoyancy ascent. The diver is now exposed to potentially greater risk of pulmonary barotrauma, entanglement, or injury from overhead obstruction. Yet this is certainly better than almost certain drowning. The general procedure is as follows:

1) Execute steps 1 through 5 as described in the controlled emergency swimming ascent.
2) Release the weight belt.
3) To gain additional buoyancy, actuate the air to CO_2 cylinder on the buoyancy vest. Remember that your reason for emergency ascent

is because you have nothing to breathe. Consequently, buoyancy units supplied with air from the regulator will probably be ineffective.

4) Exhale continuously! The ascent will probably be slow at first and will become more rapid as the vest and wet suit expand, especially near the surface. A few kicks may be necessary to initiate the ascent.

Positive-buoyancy ascents are to be used only to resolve a life-or-death situation, and no other.

I am in accord with Dr. Eric P. Kindwall (in a letter to Dr. Glen Egstrom, NAUI News, April/May 1973) who states that,

> I think one of the best ways to practice 'free ascent' is what you refer to when you state that many instructors teach ascents using the length of their pools as the depth to be handled. One of our local instructors here, after having the student ditch his gear, has him swim the length of the pool while humming. As he moves toward the shallow end, he actually is ascending and the humming insures that he is breathing out. Naturally, if he runs out of air before he reaches the end of the pool, he is in no danger of embolizing.

I have used this method for years both with and without the student wearing the cylinder.

I even go one step further in the first phase of training. I start controlled emergency swimming ascents from a skin diving mode. The student descends to the bottom of the pool on a breathhold dive (no scuba) and assumes a kneeling position. Upon signal he extends his head back, exhales, releases the weight belt, and swims slowly to the surface. As the student progresses, a similar procedure is used to swim the full diagonal length of the pool in an emergency ascent profile. This simulates an emergency ascent of about 75 feet before the student is introduced to ascent from a scuba dive.

I accept the critical comment that in this type of pool simulation "both with and without scuba" the student doesn't experience the real air volume expansion phenomenon that he would with scuba from depths of 30 to 50 feet. I don't feel that there is sufficient data to argue the pros and cons of this factor. Certainly, there is a "psychological factor" to be considered. But I feel the psychological confidence factor of practicing controlled emergency swimming ascents from these depths with scuba is not sufficient justification to introduce the potential risk of pulmonary barotrauma, at least in the early stages of diver training.

I do offer one suggestion for those who wish to practice 20 to 30 foot controlled emergency swimming ascents, or even positive buoyancy ascents in open water. Most organizations already require a "skin dive" as one of the open-water training exercises. May I suggest that you have your student descend to a given depth with scuba in place, but not breathing from the scuba. Have him drop the weight belt and execute a proper, controlled emergency swimming ascent in accord with the procedures you teach. The one difference from reality is that he is not carrying excessive air in his lungs since this exercise is executed from a breathhold dive mode. The hazards of pulmonary barotrauma have, in my opinion, been removed yet the student has the psychological conditioning of ascending from depth. He still exhales throughout the ascent.

Some instructors suggest that "simulation" procedures such as those suggested above are inadequate and undesirable substitutes for open water practice of emergency ascents. Simulation procedures are used in many activities where "real" practice is either too costly or dangerous. I feel the precedent for "simulation" is well established. However, additional research will be required to define the best and most effective simulation procedures for emergency ascent training. The above procedures may or may not be the most effective. However, using the open water technique described I have been able to expose students to 10 or more practice experiences without the hazard of pulmonary barotrauma to myself or the student.

One factor that is often overlooked in emergency ascent training and practice is the exposure of the instructor to numerous ascents. It is universally accepted that the instructor accompanies each student during each exposure on a one-on-one basis. Also most authorities agree that more than one practice exposure is necessary for each student. Consequently, an instructor who trains 100 students per year may be required to make 200 to 500 or more emergency ascent practices per year. What is the risk factor for the instructor?

As previously mentioned the buddy breathing emergency ascent is inherently dangerous and is now considered by many authorities as a third choice in emergency ascent methodology following controlled emergency swimming ascent and buoyant ascent. On the other hand, some instructors still teach this as the primary method of emergency ascent and attest to the success of the method in actual diving emergencies. My personal experience and observations suggest that buddy breathing rarely works in an actual emergency. Many attempted buddy breathing ascents end in a swimming ascent (controlled or uncontrolled) and some have apparently resulted in double drowning fatalities. Regardless of an individual's personal training and opinions, all divers must be aware of the inherent dangers as well as the advantages of buddy breathing. All divers must be thoroughly trained in buddy breathing emergency ascent procedures.

Though methodology will vary slightly with individual preferences and the type of equipment used, the following is a reasonable procedure:

1. Signal your buddy that you are out of air and wish to buddy breathe by drawing the hand or forefinger across the throat and pointing to your mouthpiece.
2. The donor will swim immediately to the victim, remove his regulator and direct it toward the victim's mouth. At the same time the donor assumes a position facing the victim and grasps the victim's harness with his left hand. This is to aid in "controlling" the victim. When using a single hose regulator, the donor may wish to position himself slightly to the left of center relative to the victim.
3. The donor always retains control of the regulator. Never let the victim have complete control of the regulator! You may not get it back. Grasp the regulator in your (donor) right hand and be certain that you do not cover the purge button. The victim guides the regulator to his mouth.
4. Many feel that it is safer to completely place the regulator in your mouth before purging the water and exhaling. To the contrary, I find that with the majority of regulator mouthpieces I can simply press the mouthpiece <u>firmly</u> against my lips, exhale (or push the purge) to remove water, and <u>cautiously</u> inhale. This saves time and, in my opinion, reduces the possibility of ingesting water. Divers should practice both ways.
5. Begin the ascent as soon as the situation is "under control." It is important to get a few breaths of air into the victim, calm the victim and establish a breathing rhythm before you compound the difficulty by swimming. So, stay where you are for a few seconds to gain "control."
6. Take two medium, quick breaths with emphasis on exhalation. The donor will initiate the ascent when he is satisfied that a rhythm has been established. Remember, as you ascend, exhale when your buddy is breathing. Air in your lungs is expanding; avoid air embolism.
7. Now comes the problem of buoyancy (or lack of buoyancy). If the divers are properly weighted and nearly neutrally buoyant you should be able to initiate ascent with a few kicks. As the wet suit and air in the buoyancy compensator expands, you will start to float upward. Both divers will possibly have to vent air from the buoyancy compensator to maintain a controlled ascent. As the ascent accelerates, keep exhaling! Let us assume that the victim is under such stress that he can not or

forgets to vent his buoyancy compensator. Should you vent it for him? Consider the following:

a) Vent most or all of the air from your unit first to control the ascent. You know your equipment better and you're less likely to disturb the victim than if you attempt to fumble with his equipment.
b) In order to do this, you will have to let go of the regulator or let go of your victim. I suggest that you vent your unit while you are breathing from the regulator. This way you retain control of both regulator and victim. The virtues of a rapidly exhausting buoyancy compensator are obvious! I admit this is an awkward and dangerous moment in the ascent procedure.
c) Grasp the victim's harness firmly and ride up on his expanding buoyancy compensator. As you near the surface, consider discharging the air from his unit if the ascent is too rapid.

8. Now let us assume that the victim (or yourself) is too heavy and you are having difficulty getting off the bottom; while still on the <u>bottom</u>, you (the donor) add air to one or both vests. Frequently, a short burst of air into your vest will provide sufficient buoyancy. This is easy if you have a mechanical inflator. Remember that your victim's scuba attached mechanical inflator will be useless at this time since his air supply is apparently not functioning or exhausted. Oral inflation may be necessary. In this case you will have to release the victim's harness or the regulator. I prefer to release the harness.
9. Remember to exhale during ascent; air is continuously expanding in the lungs. Don't hold your breath while your buddy has the regulator.
10. Some instructors advocate a "stop" at 10 to 30 fsw for a few seconds to a few minutes. Some use a stop time formula based on dive depth. This might work in practice, but I question it in actual emergencies. You have enough problems simply getting to the surface. What about decompression sickness? First, you shouldn't be in a decompression requirement dive. Second, decompression sickness is better than death by drowning!

It is almost a unanimous opinion that single hose regulator straps are a potential problem in cases where buddy breathing is required. Frequently, they cannot be easily unsnapped and thus hamper buddy breathing. Most authorities suggest that the straps be removed.

Buddy breathing may be practiced in a stationary or horizontal moving position in the pool. The basics of control, rhythm, and exhalation must be thoroughly mastered before attempting vertical ascents. Practicing vertical buddy breathing ascents is not without hazard. In fact, open-water practice must be only undertaken with extreme control. Many of the potentials of accident with subsequent pulmonary barotrauma are present. In my opinion, this is not an exercise for a novice during his first exposures to open-water diving. Even when practiced, a very slow controlled ascent up a static line is desirable. Even when the divers practice buoyancy control ascents without grasping the line, it is desirable to have the line immediately adjacent to the students so they can grasp the line for control. A supervising instructor or assistant should accompany the students. An alternative method of practice control is to place safety divers at 6 to 10 foot intervals along the line. Students must be informed that they can abort the ascent at any time and start using their own scuba or a safety diver's octopus unit.

At this time, the controversy over which emergency ascent procedure to use has not been totally resolved. One national scuba diver training program requires extensive practice and testing using buddy breathing. Mount (1976) emphasizes that buddy breathing should be performed at least 200 to 400 yards during each pool session and has developed a number of exercises to complement the training procedures. Mount emphasizes that the use of free ascent should be <u>discouraged</u> as the first choice in self-rescue. As previously stated, Hardy (1976) emphasizes the controlled emergency swimming ascent as the <u>first</u> choice in self-rescue and considers buddy-breathing as the <u>third</u> possible alternative.

Mount further supports his position with examples of actual successful uses of buddy breathing to resolve <u>real</u> diving emergencies. I too am aware of <u>some</u> successful uses of buddy breathing in real emergencies. I will concur with Mount's position with the following specific qualifications:

1. The divers must have been training in a course which places considerable emphasis on buddy breathing both in skill practice and theory lectures.
2. During training the diver must have practiced the skill 20 or more times under various conditions.
3. The diver is a skilled swimmer and totally "at home" in the water.
4. The diver is always in a situation which allows him to choose a buddy with equivalent training in buddy breathing and emergency procedure philosophy.
5. Both divers in the buddy pair have routinely "practiced" buddy breathing since training.
6. The individuals involved are active divers. They should log 30 to 50 scuba dives per year.

7. The two divers involved dive together on a routine basis.

Under the above conditions I am certain that buddy breathing might be a logical choice of emergency ascent technique.

Now let us examine the other side of the coin. Another national training organization emphasizes controlled emergency swimming ascents or the exclusive use of an auxiliary breathing unit (octopus) as the proper emergency ascent procedure. During the open-water portion of a course, both simulated controlled emergency swimming and buoyancy assisted ascents are often required. On the other hand, apparently only the "octopus" is emphasized throughout training by at least one organization.

The following "realities" of the sport diver must also be considered:

1. Divers seldom if ever practice buddy breathing following training. Even an "overlearned" skill soon becomes inefficient or ineffective if not practiced.
2. Many divers do not have the same diving buddy for each dive.
3. Diving buddies are frequently trained by different philosophies on emergency ascent. Seldom do they discuss their varied opinions prior to diving together.
4. The average diver is probably not a skilled swimmer. Increasing emphasis on buoyancy compensation has allowed a large number of poor swimmers to enter the field of diving. A person who is a poor swimmer and "not at home" in the water is more likely to "break" under the emotional stress of a life or death emergency.
5. The average diver does not make 30 to 50 dives per year. Ten to 12 exposures is a more realistic number.
6. The average diver does not dive on a regular basis. Often the annual dive number is concentrated in one or two vacation trips or during summer months.
7. The average diver is trained under a "diving is fun" philosophy. He is not schooled in the psychology of stress as related to diving.
8. The average diver does not, in my opinion, have and/or maintain the necessary skill proficiency to execute emergency buddy breathing ascents safely under real emergency conditions.

I am greatly concerned about the diverging philosophies on emergency ascent training. The diving community must somehow "standardize" in this critical area. I am concerned for the two novice divers who meet on a charter boat for the first time.

Unknown to the two divers, one is trained as a "buddy-breather," the other as a "free-ascender." At 100 fsw one diver finds himself without air. Each takes the "appropriate" action in accord with their training. The most probable outcome is a "double drowning."

What is the solution? I have examined the pros and cons of buddy breathing and controlled emergency swimming ascent. At least for the time being divers must be trained and skilled in both. Emergency procedures must somehow be standardized! The use of an auxiliary or emergency breathing system seems to be the most logical solution. Commercial divers use back-up systems. Why can't sport divers? Sport parachute (sky diving) participants carry an emergency parachute. On the other hand, most divers find the use of an octopus regulator or secondary scuba to be "too expensive." A recent survey of Michigan and Ohio divers revealed that only 24 percent of the sport divers own an octopus regulator or emergency scuba. Many of those divers who do use octopus regulators allow the emergency second stage to drag in the sand and otherwise abuse it. This type of negligence may render it inoperative. In addition, the diving industry has apparently devoted only a token effort to developing an acceptable specialized emergency breathing system. The octopus regulator was conceived by diving guides and instructors, not design and life-support systems engineers. The auxiliary scuba (pony tank) was a "home-made" product of the cave diving community, not the equipment manufacturers.

Ultimately, universal use of special emergency breathing equipment is probably the best and most ideal solution. However, at present comprehensive training and perfection of skills in both buddy breathing and controlled emergency swimming ascent appear to be the only reasonable approach.

A FALSE SENSE OF SECURITY

I am certain that thousands of simulated emergency controlled swimming ascents are performed each year without adverse incident. Although this is a subjective statement I feel it is true or we would have a higher mortality rate in scuba diving today. This has led many instructors to a false sense of security. Many feel, "it couldn't happen to one of my students or myself." Let us examine this concept.

1. Pulmonary barotrauma is being documented in sport diving emergency ascent training.
2. The probability of respiratory tract abnormalities is higher in smokers than non-smokers and thus the potential risk of pulmonary barotrauma. Consequently, the instructor is encouraged to use considerable discretion in dealing with this group of diving students. Based on my observation on

campus and in junior high schools, smoking is as prevelant among young students as ever. Youth in itself is not necessarily a measure of respiratory fitness.

3. Respiratory abnormalities do disqualify a small but significant percentage of scuba diving class applicants. If students are accepted and trained without prior medical examination, this small percentage group represents a significant risk in normal diving activity, particularly in emergency ascent training. Medical examination or clearance before open water or certification is, in my opinion, an unnecessary risk. Medical examinations must be prior to acceptance for scuba training. Evaluation of a medical history form by an average instructor is insufficient for detecting physical abnormalities.
4. Even in apparently healthy divers who have medical clearance for diving, day-to-day respiratory infection can cause restriction or blockage of air egress from some areas of the lung. The consequences are evident.
5. Many instructors teach the "blow and go" emergency ascent technique, where the student exhales to residual volume, and then starts ascent while continuing to exhale throughout. When a person exhales to residual volume, it is well known to pulmonary physiologists and physicians that some of the smaller airways with lesser amounts or no cartilagenous tissue will collapse. This may restrict normal egress of air. Combine this phenomenon with bronchial congestion or lung abnormalities (as in a lung affected by current or prior disease or smoking) and there is a relatively significant potential for "air trapping" with subsequent pulmonary barotrauma (personal communication, John Dircks, M.D.).
6. You say as an instructor or advanced diver that the odds are in your favor. I agree, at least in young, healthy, medically qualified, non-smoking divers. But what about the instructor. Students may make only one or two deep emergency ascents in a year of diving. Instructors may train 50 to 100 students per year and make one or two emergency ascents with each student. How many simulated controlled emergency ascents will you make in a lifetime? What is your risk?

I'm certain that portions of this text have bordered on the "doomsday syndrome." For this, I apologize. However, I feel it is necessary for each and every instructor and diver to take time every so often to re-evaluate and to reflect on his or her teaching program and individual diving procedures. I hope this text has served as an incentive for you to do just that.

In conclusion I find myself compelled to make the following statements to the diving community:

1. The emergency controlled swimming ascent is a vital and necessary part of basic scuba diving training.
2. The procedure must be "overlearned" so that divers will use it, without hesitation, when appropriate (in accord with Egstrom, NAUI News, February/March 1973).
3. Numerous exercises, many used in the pool both with and without scuba, should be performed to enhance the student's development of skill and confidence relative to emergency ascent.
4. The controlled emergency swimming ascent is probably more desirable, workable, and possibly even safer than buddy breathing ascents for the average shallow water diver.
5. Prior to practicing emergency ascents all divers must pass a medical examination with, preferably, a chest x-ray.
6. Smokers represent a "greater risk" for any type of emergency ascent training, even in the swimming pool.
7. Overemphasis on buddy breathing without proper training must be arrested. Students must be physically and psychologically prepared for the adverse consequences of unsuccessful attempts at buddy breathing. They must be prepared to chose between the buddy breathing and the controlled swimming emergency ascent, depending upon conditions and the situation.
8. Positive buoyancy emergency ascents must, not may, be taught in principle but practice of such procedures in both pool and open water is discouraged.
9. The practice of both controlled swimming and positive buoyancy emergency ascents may be accomplished from a skin diving mode with little risk and a relatively high degree of student confidence and skill development.
10. Practice of controlled emergency swimming ascents in open water may or may not be necessary. There are not sufficient data to support unqualified inclusion or rejection as a training exercise at this time.
11. Pulmonary barotrauma in sport diver emergency ascent training is a certain and real occurrence. Cases have been documented.
12. Abuses of and the emphasis on buoyancy compensation diving is further complicating the emergency ascent problem. Avoid weighting the diver so that excessive buoyancy compensation is required.
13. We all teach "diving is fun." But, you must inform your students of the significant risk involved with emergency ascent training, even under pool conditions.

14. Auxiliary breathing systems are desirable if universally used and properly maintained.
15. Candidates for diving training must be screened on a basis that emphasizes a "higher level" of fitness and watermanship than is commonly accepted by the recreational diving community today.
16. Training exercises and procedures must be directed toward "prevention" of air supply depletion underwater.
17. Do not operate under a "false sense of security!"

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LEGAL ASPECTS OF EMERGENCY FREE ASCENTS

John Remon Wenzel

This paper sets forth several legal considerations that should be explored in establishing any policy concerning free ascent training. Of particular concern in this age of consumerism are the tendencies of courts to find instructors wrong and to permit insurance carriers to settle questionable cases without defending them in court. Liability insurance costs for instructors may accelerate beyond reach and perhaps the insurance itself may become unavailable. A compromise policy of training is proposed for the present. For the future, an emergency, redundant breathing system may be safer and more easily defended.

INTRODUCTION

The proliferation of definitions on just what constitutes free ascent training for the sport diving public has caused significant difficulty. However, it appears that most would agree that, for the sport diving public, it is a broad term, referring to an ascent to the surface from depth without inhaling while scuba diving. Thus, the last breath was taken at depth, at ambient pressure from scuba. The ascent may include swimming, buoyancy changes through vest inflation and/or weight belt dropping, or by a rapid or normal (60 ft. per minute) ascent rate.

There seem to be two distinct schools of thought concerning training in this technique. One says do it and one says don't. The first says it may save a life and thus ought to be taught and practiced under close supervision. The second says that since occasional air embolism and death occur, it should not be taught, particularly when one considers that true out-of-air emergencies are fairly rare(Hardy 1977), and the need to make such an ascent probably will never happen.

A PROPOSAL

There is a third school of thought developing as a compromise. It is at best only fuzzily defined but may offer the best solution right now, given the current state of the art in the areas of both equipment availability and pulmonary physiology.

That third school of thought suggests that free ascent training be conducted approximately horizontally in a swimming pool and that open water vertical ascent training be limited to air-on, regulator-in-mouth exercises. When examined carefully, this policy satisfies the major positions of both camps and may stand up legally as well. I refuse to be more definite on the legal conclusion made because legal conclusions never have the accuracy provable by the scientific method.

A major argument advanced by the anti-free-ascent camp is that, if an accident should occur during training, the instructor may be hard pressed to justify his behavior when the inevitable legal action is brought. Furthermore, evidence of the practices of others, notably the Navy which requires the presence of chambers and medical personnel in submarine escape practice, may destroy the instructor's case (Kindwall 1976).

The relevancy of testimony of Navy practices might be questioned in the ensuing legal action. However, of far greater concern to this author is the specter of a possible lawsuit involving an unsuccessful free ascent attempted by a former student who was never trained in the procedure. When this cake receives the icing provided by the age of consumerism, which dictates that the only real question is not liability but, simply, "how much do we pay", then it is only reasonable to conclude that some form of free ascent training should be given the sport diving public.

A major argument advanced by the pro-ascent training forces, particularly those advocating more exotic practices, such as air-off, regulator out-of-mouth training, is that it needs to be done to give the student necessary training in a somewhat difficult skill that may save his life.

From a legal standpoint, I have a major difficulty in accepting even the possibility of one free ascent casualty in the training environment, particularly a fatality. And we have had at least one, apparently when the exercise was conducted under the best of circumstances (McAniff 1976). Unlike the Navy, which can accept the inevitability of such things in submarine escape training, the sport diving industry cannot afford even one fatality. Again, I must point out that in this age of consumerism, the only question will be: "how much do we pay?" One such settlement a year by the insurance company involved is troublesome but two or more may dictate the end of insurance availability. To teach diving without insurance protection is completely foolhardy (Wenzel 1976).

Worse yet, the jury is still out as to a scientifically reliable explanation for some of the injuries sustained due to free ascents.

Legally, it is unwise to conduct such a training activity when we don't really know what may happen and how to prevent it.

It is submitted that the third school of thought herein proposed is the best of the Catch 22 possibilities currently available, from a legal standpoint. It is admittedly a compromise position accepting the major arguments of both sides of the fence.

A better answer for the future may be to reexamine the fundamental need for the skill in the first place. As a threshold matter, it is submitted that emergency procedures requiring extensive training and periodic reinforcement may be unsound. It seems more reasonable to develop free ascent skills which are simplified and require as little skill or exercise of judgment as possible. For example buddy breathing is considered by many to be unacceptable just because it is so hard to learn and even harder to remember.

Conversely, a solution for an out-of-air emergency which involves merely switching to a 100% redundant breathing system followed by an ascent to the surface may eliminate the need for free ascents - in the future (Somers 1976). The skill level required and reinforcement needed for this exercise appear minimal. Such a system is more easily defended legally as well. After all, sky divers have two parachutes, don't they? (Like it or not, most judges think we are as crazy as sky divers and often mention us in the same breath when considering recreational activities considered to be foolhardy).

CONCLUSION

Legally, there is no hard and fast answer to the current dilemma of free ascent training. However, the evolving of as safe a compromise position as is possible between the pro and anti-forces seems reasonable. The eventual answer to the problem may be found in equipment modification by providing a 100% redundant breathing supply.

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A POSITION PAPER ON EMERGENCY ASCENT TRAINING

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December 7, 1977

THE QUESTION

This paper addresses the issue of the need for and the desirability of training recreational divers in emergency swimming ascent procedures. This issue should not be confused with the issue of the desirability of emergency swimming ascent as an option for recreational divers in a sudden out-of-air situation. The National YMCA Underwater Activities Program and I personally support the position shared by other participants in the National Scuba Training Committee, which lists emergency swimming ascent as the primary independent option for recreational divers experiencing a sudden termination of air supply at depth. The question at hand pertains to the need for and nature of training to be required in this procedure to assure competence in an actual emergency situation.

THEORETICAL ISSUES

Well-established theory in training and education supports the principle that the performance of a complex motor activity such as emergency swimming ascent in open water can be enhanced through training. Additional theoretical constructs support the notion that training value increases as the similarity of the practiced skill approaches that of the actual skill required. This would lead one to conclude that the highest level of proficiency in open-water emergency ascent could be achieved through the performance of open-water emergency swimming ascents during training. This does not discount entirely the potential value of other forms of training, including simulation, as reasonable tools for skill development. Simulation is a highly acceptable form of training in fields involving high levels of performance in hazardous situations.

Other theoretical evidence suggests that the performance of emergency swimming ascents in open water either in a training or an operational context presents certain physiological hazards to the diver involved. Medical theory suggests that the presence of certain lung pathology or the failure of the diver to perform certain methodological functions such as adequate ventilation can produce lung damage and ensuing cerebral air embolism during emergency swimming ascent. Behavioral theory suggests the possibility of human error in the attempts to perform these methodological functions, with similar medical consequences.

EMPIRICAL DATA

Empirical data gathered on the basis of actual diving accidents indicate that cerebral air embolisms do in fact occur as a result of emergency swimming ascents in both a training and operational context. Sometimes these pulmonary accidents are clearly associated with errors in performance of the technique required; at other times they are not. The presence of lung pathology also has on occasion been associated with the occurrence of pulmonary accidents during emergency swimming ascents for training and operational purposes, although a clear cause and effect has seldom if ever been demonstrated. Empirical data from field experience also show that instructors on occasion fail to utilize the procedures specified by the training agencies with whom they are affiliated during the performance of emergency swimming ascent training in open water.

It is a matter of record that medical examinations capable of detecting lung pathology of theoretical relevance to barotrauma during emergency swimming ascents are not required by any of the commonly recognized recreational diver training agencies. In fact, only the YMCA requires any medical examinations at all.

The evaluation of student performance during training and in subsequent field experiences indicates that a high degree of proficiency in the performance of emergency swimming ascents in open water can be achieved through a variety of training techniques exclusive of as well as including the performance of actual emergency swimming ascents in open water. Recent studies at the National YMCA Center for Underwater Activities reveal no significant difference in training effect between divers heavily trained through simulation plus an open-water emergency swimming ascent experience and other divers given identical training with the exception of the open-water emergency swimming ascent experience.

CONCLUSION

The writer's conclusion based on the evidence presented above is that emergency swimming ascent training should be pursued with great vigor by recreational diving instructors through any techniques currently available for this purpose, with the exception of open-water emergency swimming ascents using compressed air. The summary reason for this conclusion is that the casualty rate which is empirically associated with the performance of open-water emergency swimming ascents for training purposes is not warranted by the training value of this technique over and above the lower risk training methods.

NAUI POLICY ON ASCENT TRAINING

Jon Hardy
NAUI Executive Director

December 7, 1977

INTRODUCTION

Underwater instructors have a significant moral and legal obligation for the continued health, safety and enjoyment of student divers both during and after scuba training. Unique to scuba diving are radical pressure changes,which create a potential special risk during all underwater activities.

In spite of the extensive "preventive measures" provided to sport scuba divers during training, divers still have difficulties that cause them to surface under emergency conditions both during training and later while sport diving. Knowing this, instructors are obligated to provide adequate training to deal with these emergencies and ascend to the surface safely.

Agreement within the diving community on how a diver should ascend is not complete. However, dialogue and understanding of each agency's "position" has greatly improved with the recent National Scuba Training Council Emergency Procedures Statement.

Prescribed training techniques for ascents differ substantially, yet both morally and legally constitute a great responsibility. Each instructor association has developed and is using different ascent procedures. This is not in the best interests of students or sport divers.

My request is this: We each enter this workshop with an open mind, searching for a compromise solution that is in the best interests of students and sport divers. We must not be held back by our "own" procedures or by the fact that we all printed many manuals with only "our" procedure. Times, needs and equipment change - so we must all change for the continued well-being of the sport.

BACKGROUND

Due to the special risks involved in scuba ascent training and the hazard to students in their later diving if not prepared to make ascents under emergency conditions, this policy statement is provided as a supplement to the NAUI Standards for all Diving Courses.

DEFINITIONS

Buddy Breathing - The sharing of air between divers; may be used as an ascent during emergencies. Also used to swim horizontally during certain emergencies or to allow divers to regain composure before making another type of ascent.

Buoyant Ascent - An ascent made using some form of positive buoyancy, such as wet suit without weight belt, vest or BC inflated, done more rapidly than the normal ascent. Not a form of controlled ascent.

Controlled Ascent - Any one of several ascents including normal, swimming and buddy breathing ascents, where the diver maintains control so a pause can be made during the ascent.

Emergency Ascent - An ascent made when the diver is low on or out of air. May also be used to refer to an ascent made when the diver is under excessive stress.

Free Ascent - A form of submarine escape. Not used in diving but the term is often confused with the swimming ascent. A free ascent does not use equipment but breath control to provide buoyancy, and is considerably more dangerous than the ascents used in diving.

Normal Ascent - An ascent made with an adequate air supply at a rate of 60 feet per minute.

Swimming Ascent - An ascent which can be done under normal or emergency conditions accomplished by simply swimming to the surface. May be aided by some positive buoyancy from a buoyancy control device.

TRAINING

Lecture - The instructor is to cover ascent definitions, criteria for selecting a method of ascent, ascent concerns or hazards, prevention of emergency ascents, a plan of action, and procedures for swimming ascents, buoyant ascents and buddy breathing.

Pool or Confined Water (8' to 16' of clear, calm, warm water) - Swimming ascents under normal and simulated emergency conditions and buddy breathing are to be practiced under the direct supervision of an instructor. Buddy breathing is to be done in a stationary position and while swimming both horizontally and vertically.

Open Water (20' to 40') - Swimming ascents under normal and simulated emergency conditions plus buddy breathing are to be practiced under the direct supervision of an instructor. Buddy breathing is to be done only in a stationary position or while swimming horizontally, NOT vertically. Emergency swimming ascents are to be done only on a 1 to 1 basis with the instructor in contact and in control of the student.

Procedures - ALL ascents are to be done with the regulator in the mouth and with the student looking at the surface. The student IS NOT TO BE placed under any undue stress. The student is to be allowed to abort an ascent anytime by stopping and breathing from the regulator.

Buoyant ascents after breathing compressed air from scuba are NOT to be practiced. Students may, as skin divers, practice weight ditching, BC inflation and the flare technique for ascents.

The use of a line which is anchored and buoyed from the bottom to the surface is recommended for ascent training.

In case of an emergency during training the instructor is to be prepared with the location and phone number of the nearest chamber, the phone number of the emergency agency to be used for transportation and the phone numbers of two diving doctors.

The instructor and all those assisting the instructor are to be trained in the first aid for lung over-pressure accidents.

SUGGESTED LECTURE OUTLINE

I. Introduction

  A. State the problem
  B. Overview
  C. Definitions:
    1. Buddy breathing
    2. Buoyant ascent
    3. Controlled ascent
    4. Emergency ascent
    5. Free ascent
    6. Normal ascent
    7. Swimming ascent

II. Criteria for selecting a method of ascent

  A. Distance to buddy
  B. Distance to surface
  C. Diver stress level

D. Obstructions to ascent

  1. Cave
  2. Wreck
  3. Heavy kelp
  4. Ice

E. Reason for air loss

  1. Low on air
  2. Over-breathing
  3. Equipment malfunction
  4. Totally out of air

F. Skill training and practice (particularly with buddy)

G. Type of equipment, such as BC and regulator

III. Concerns and hazards

A. Air embolism and related injuries
B. Decompression sickness
C. Diver stress and errors in judgment
D. Drowning
E. Ego threat
F. Equipment loss
G. Fatigue and cold

IV. Prevention

A. Breathing habits
B. Buddy diving
C. Buoyancy control
D. Continued training
E. Dive planning
F. Diver fitness
G. Gauge and reserve
H. Limitations and a margin of safety

V. Action plan

A. Stop, breathe easy, think
B. Check situation

  1. Distance to buddy
  2. Distance to surface
  3. Buoyancy

4. Gauge and reserve
5. Obstructions to ascent
6. Reason for air loss
7. Stress level

C. Forced choice method

1. Make an emergency swimming ascent
2. Make a buoyant ascent
3. Make a buddy breathing ascent or escape
4. Methods may be changed during ascent

VI. Procedures

A. Swimming ascent

1. Keep regulator in mouth
2. Look at surface
3. Use BC if possible
4. Swim while exhaling
5. Try breathing in
6. Be ready to drop weights

B. Buoyant ascent

1. Release weights or inflate BC
2. Look at surface
3. Exhale rapidly
4. Dump air from BC to slow ascent
5. Flare to slow ascent

C. Buddy breathing ascent

1. Get control together
2. Adjust for neutral buoyancy
3. Maintain contact by holding and eyes
4. Donor on the right in control of mouthpiece
5. Two breaths per exchange
6. When not on scuba during ascent, look up and exhale
7. Blow to clear, but keep purge clear
8. Take it slow and easy
9. Be ready to change method if buddy's air is exhausted

VII. Special considerations

A. Use of octopus regulator
B. Rate of ascent as near normal as possible

C. Independent action (swimming and buoyancy ascents) versus, dependent action (buddy breathing)
D. Make emergency ascent as near normal ascent as possible
E. Continuous buoyancy control
F. Proper terminology is important
G. Diver error causes emergency ascents

VIII. Summary

A. Definitions
B. Criteria
C. Hazards
D. Prevention
E. Action
F. Procedures
G. Considerations
H. Importance
I. Choices

1. Swimming
2. Buoyancy
3. Buddy breathing

EMERGENCY ASCENT TRAINING

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Medical Director, Tobermory Hyperbaric Facility

The various instructor organizations in the world have been plagued for some time now with the problem of what to teach about emergency situations and how to teach it without incurring excessive risk to students and liability to themselves. Already rates for instructor insurance are climbing as the courts demonstrate willingness to increase the scope and degree of liability by their awards. This situation has led to serious recommendations at national meetings of instructors' organizations that nothing be taught to novice divers about emergency ascent, that it should be reserved for advanced classes. Such actions would be tantamount to suggesting that only pilots who survive the first year should be taught how to do emergency landings.

In considering the matter of emergency ascent we must of course recognize that once panic occurs our ability to influence the outcome ceases. The remainder of this submission is directed at the diver who is still in control in an effort to examine his options and hopefully develop a logical course of action which, if followed, will both prevent panic and ensure the safest possible ascent.

It is perhaps relevant to point out at this juncture that teaching a technique doesn't necessarily involve practicing it. The F.A.A. suspended practice of forced landings because such practices too often turned into the real thing. In the same vein it should perhaps be pointed out, here, that the inappropriate nature of the initial response to emergencies is what converts many mishaps into disasters. Professional instructor organizations have prepared various statements on ascent training, culminating in the National Scuba Training Council Ascent Agreement.

In this agreement, the first two options to be presented to students are:
1. The use of octopus regulator
2. Buddy breathing

Both of these alternatives are taught in Canada as elsewhere, despite the fact that in our very cold waters, doubling the mass flow through the first stage significantly increases the chances of freeze-up, which will deprive both rescuer and victim of air. Buddy breathing is also fraught with difficulty in waters which leave one's lips too numb to feel. Perhaps more significant are the omissions. Nowhere does this document mention the importance of psychological preparation. It fails to suggest immediate movement upward if difficulty is even suspected; worse, it suggests evaluation before taking any action. Would it not be better to take conservative immediate action while evaluating, e.g., signal to buddy and commence a normal ascent at once?

What remains to be determined now is the safest way of executing an emergency ascent, if this becomes necessary. A great deal of information exists about various methods of rapid ascent (buoyancy assisted) and as this represents the most extreme case, any technique which is successful in this instance must embody principles important in all ascents. First, it has been apparent that a closed glottis is a potential hazard from earliest times. Passively holding the glottis open is a difficult feat; reflexes tend to close it at all times when respiratory activity doesn't require it to be open. Recently in Toronto Sick Childrens Hospital, while conducting a study using physiologist-physicians as subjects, Dr. A.C. Bryan found only four of nine could perform this act. To avoid this problem Steinke advocated having the subjects' heads covered by a hood containing air and teaching them to keep breathing. The success of this technique shows the validity of his concept. Still, there are failures. Some of these failures have been attributed by Behnke and others to small airway closure and subsequent air trapping. Techniques have been suggested to avoid this but, to date, no detailed explanation has been published relating the pulmonary dynamics during the ascent to the potential hazards. We know from work by a large group of researchers, including Macklem et al. and Frey et al., that we all produce closure of some small airways with each expiration; the precise percentage varies from 10% for healthy 18-year-olds to 40% in 65-year-olds. In water in a vertical position, due to the pressure gradient applied to the chest wall, there is an increase in this trapping at the bases, as shown by Dahlbäck and Lundgren. If we examine now a sequence of alternatives for a hypothetical lung, perhaps the difficulties will be more readily appreciated. As our principal concern is with sport divers, a suitable depth from which to start their hypothetical ascents would be 50 feet, with the diver starting at or near F.R.C., as the diver most frequently becomes aware of his plight when he attempts to breathe in after normal expiration.

At this point (see Diagram 1) the state of affairs in the lung can be represented as shown. The precise ratio of patent to closed alveoli would vary with the lung zone. In the normal person above water, the collapsed segment reopens with the next deep breath or sigh. The diver cannot do this if he is out of air, but he has several options open to him. First, he may elect to blow down to R.V. and then hold his breath to the surface, or "blow and go." As the glottis is closed during this manoeuvre, if the ratio of R.V. to T.L.V. for the subject exceeds the ratio of pressures passed through during ascent, a burst lung will result. A young healthy diver will permit a ratio of R.V./T.L.V. of 1/3.5 and so will escape this problem in our hypothetical case. Older divers will not be as fortunate, as their ratios may be exceeded, depending on their respiratory status. For the fortunate diver who escapes this consequence of Boyle's Law, let us examine the sequence of events in the lung as he rises toward the surface. The intrapleural pressure starts off negative. As the lung expands, it becomes less negative due to the attempt to rebound to F.R.C. (F.R.C. in water is lower than F.R.C. in air), but as the gas in the lungs expands, it too becomes positive. The force which produced the interdependence forces has been restored by parenchymal expansion. The dynamic flow situation leading to the locating of the Equal Pressure Point of Mead, Macklem and others within the collapsible segment of the airway is no longer present, as glottis is closed and flow has ceased. In addition, expanding alveolar gas leads to increasing alveolar pressure, which assists in airway opening. In conclusion, then, this would seem a reasonable approach for young divers with no anatomic anomalies or scars which might lead to the trapping of excess gas provided they can be certain they are in 60 feet or less of water.

The next alternative is the most widely taught response. The diver rises to the surface, blowing out as he goes. If we examine this situation, a potential hazard becomes apparent. If one of the alveolar units closed during the expiration contains more than 1/3 of its potential volume and if the diver maintains expiration to the surface from 50 feet, it may rupture. Note that the first alveolar units to close are those with the lowest elastance or highest compliances. The continuance of the expiration maintains the dynamic flow force which produced the closure, surface tension forces assist in this regard, and interdependence forces are prevented from becoming significant by the lack of lung expansion. Any interrruption in this expiration, especially any attempt at inhalation, can rapidly alter this sequence of events, a fact which I feel has saved many divers. Whether the pressure required to burst an alveolus in this situation is lower than that required to open the closed airway has not been proven, but the possibility exists and would explain most of the unmerited burst lungs we see.

The next alternative to be explored is the possibility that the diver could ascend, attempting inspiration all the way. In this situation the pleural pressure remains negative at all times. The interdependency forces grow as the lung expands, assisting in opening closed airways. The glottis is open and the airways maximally patent, so outflow resistance is minimal and the gas free to behave in accordance with the dictates of Boyle's Law, unless the ascent rate exceeds the maximum rate seen with the Steinke hood, which is improbable; the flow rate generated by the effects of Boyle's Law would be of the order of 3-4 litres per second, which is well within the limits of rates measured in exercising. This then might be the best of the alternatives for very rapid ascents but needs further investigation, and because the procedure is psychologically difficult, it may never be the best for sport divers (see Diagram 2).

Sport divers' rates of ascent even when buoyant would rarely approach 200 feet minimum unless using Unisuits, but the benefits of the continuous inspiration may be achieved in most cases by simply maintaining a cycle of respiration. This will ensure the glottis is kept open and that pressures are cyclically altered so that in the inspiratory phase, opening of small airways is encouraged. The students should be taught to emphasize deep inspirations and to increase the rate of respiration with the rate of ascent.

At the rate of ascent encountered in submarine escape, a normal rate of respiration could easily lead to the subject being in expiratory phase all the way from 60 feet to the surface, thus resulting in a burst alveolar unit. This could perhaps be avoided by either continuous inhalation or rapid panting at relatively higher lung volumes during ascent.

As an instructional unit our next concern here was with methods of instruction. To reduce the psychological shock caused by out-of-air situations, we teach all our students to expect to run out of air on every dive. We teach them to do the usual safety check, and to use underwater gauges and octopus regulator. We also teach them not to argue with their gear, underwater. Regardless of what the underwater gauge says, if you are having difficulty getting air comfortably, signal your partner and start up gently. If the problem is simple and you rectify it, the time to return to bottom is short. If the problem is progressive, the time saved by the immediate start up may prevent panic and save life.

To train actual emergency ascent, we proceed as follows. In the pool, we have students swim up along the bottom slope, breathing in and out; we increase the speed and emphasize the need to breathe in and out. Next, in 10 feet of water, we shut off the students' tank with a hand on the valve, watch to ensure they encounter the difficulty, i.e. breathe out and fail to get air, then swim with them as rapidly as possible up the slope, watching to ensure that they seem to attempt to maintain a cycle of respiration. This procedure is discussed and repeated as often as needed to get the student comfortable. We repeatedly emphasize that you maintain breathing in and out or attempting to do so against dry regulator or closed lips, and that you increase the rate of this cycle if you are ascending more rapidly. Finally, we repeat the drills in open water using repeated swimming and buoyant ascents with air on to depth of 25 feet, and air-off ascents gradually increasing from 10 to 30 feet on a tethered line, one on one, instructor's hand on the air valve.

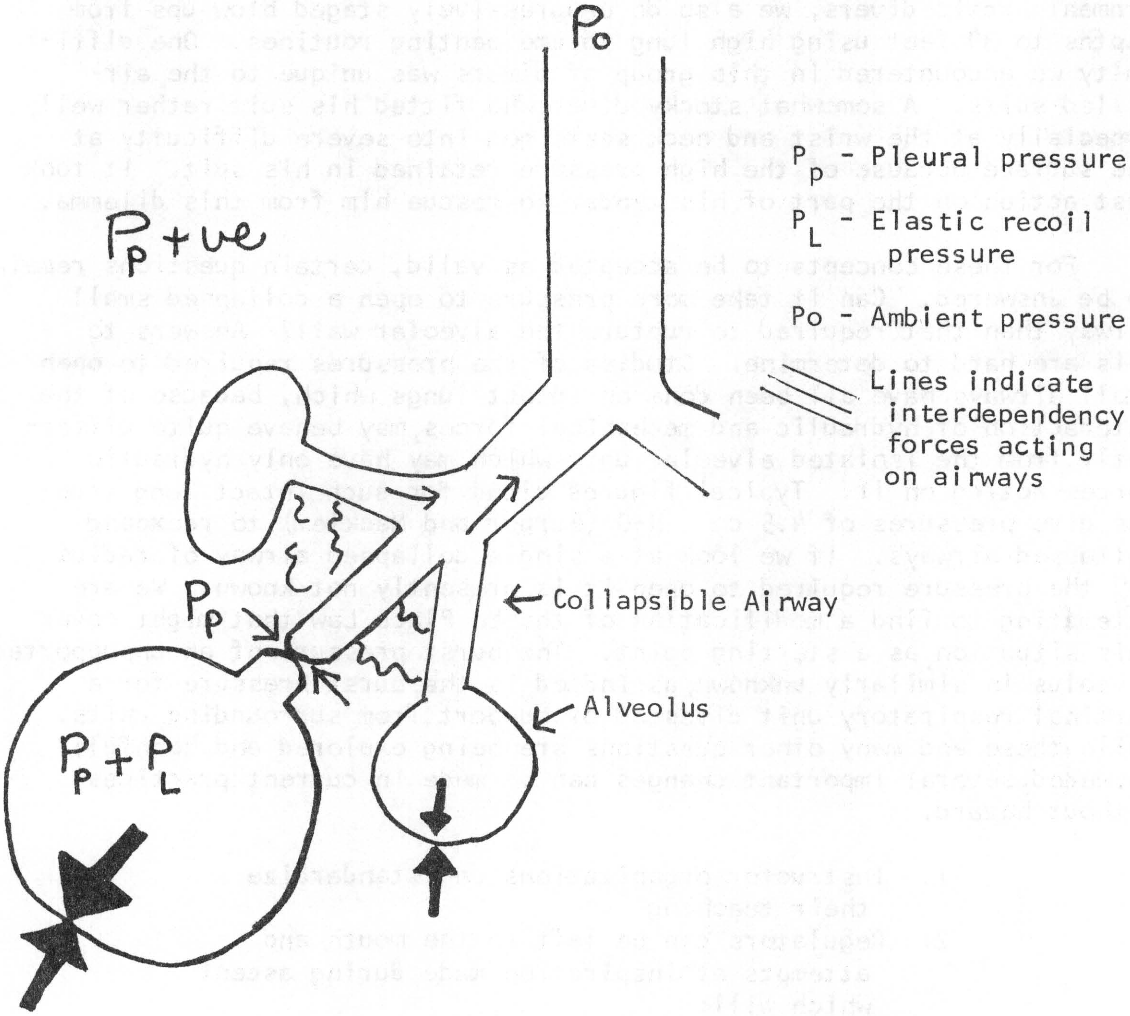
For special candidates who dive with Unisuits, e.g., Canadian Government Arctic divers, we also do progressively staged blow-ups from depths to 30 feet using high lung volume panting routines. One difficulty we encountered in this group of divers was unique to the air-filled suits. A somewhat stocky diver who fitted his suit rather well, especially at the wrist and neck seals, got into severe difficulty at the surface because of the high pressure retained in his suit. It took fast action on the part of his tender to rescue him from this dilemma.

For these concepts to be accepted as valid, certain questions remain to be answered. Can it take more pressure to open a collapsed small airway than that required to rupture the alveolar wall? Answers to this are hard to determine. Studies of the pressures required to open small airways have all been done on intact lungs which, because of the interaction of hydraulic and mechanical forces, may behave quite differently from the isolated alveolar unit which may have only hydraulic forces acting on it. Typical figures cited for such intact long studies give pressures of 4.5 cm H_2O (Burger and Macklem) to reexpand collapsed airways. If we look at a single collapsed airway of radius "r," the pressure required to open it is presently not known. We are attempting to find a modification of the La Place Law that might cover this situation, as a starting point. The burst pressure of an unsupported alveolus is similarly unknown, as indeed is the burst pressure for a terminal respiratory unit divested of support from surrounding units. While these and many other questions are being explored and hopefully answered, several important changes can be made in current practices without hazard.

1. Instructor organizations can standardize their teaching
2. Regulators can be left in the mouth and attempts at inspiration made during ascent which will:
   (a) reduce tendency to panic
   (b) provide air from the tank, thus delaying onset of hypoxia
   (c) reduce any chance of alveolar rupture due to trapping

There remain other problems, but perhaps from this workshop there will be the beginnings of an organized effort to eliminate these gaps in our knowledge so that some definitive solutions can be found.

Abbreviations used in this paper include FRC (functional residual capacity), RV (residual volume), and TLV (total lung capacity).



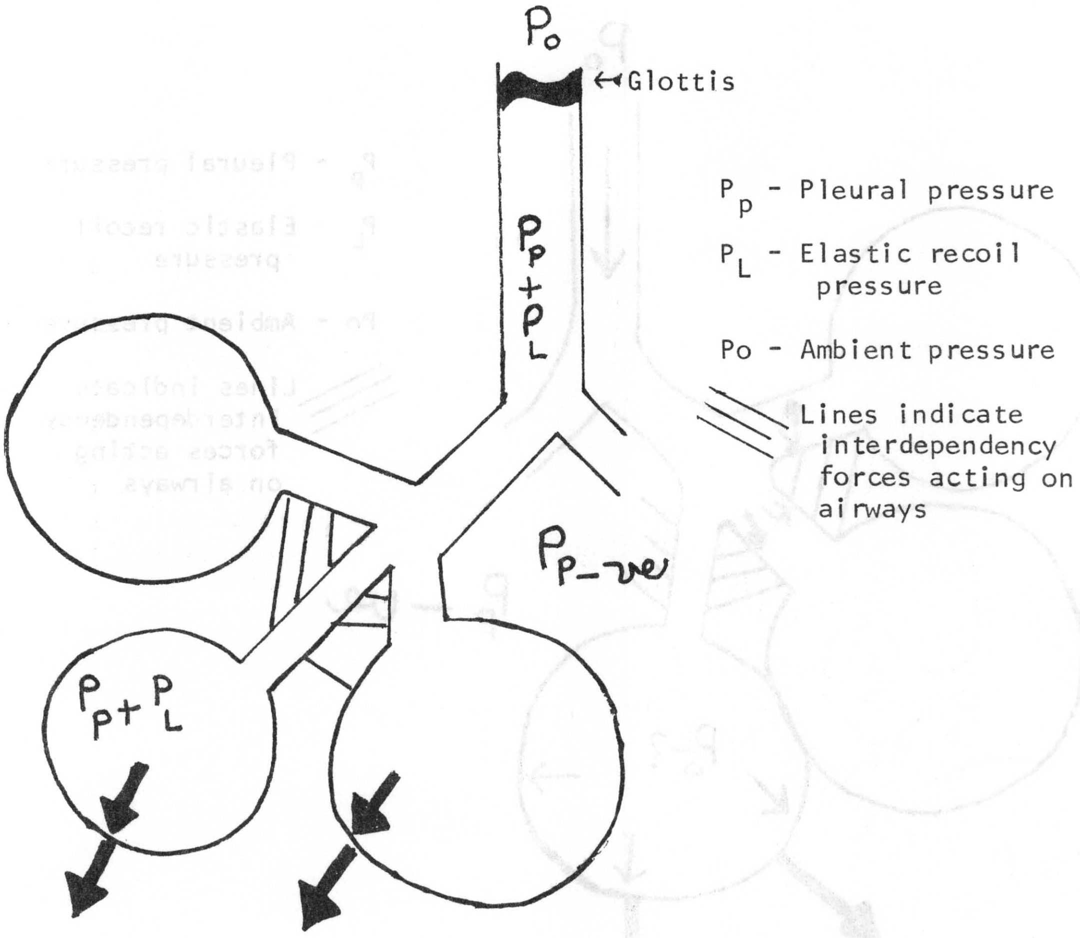
Represents situation during ascent with continuous expiration.

Note force promoting closure: (a) High P_p

(b) Interdependency forces are slack

(c) Surface tension forces (not shown)

Diagram 1



P_p - Pleural pressure

P_L - Elastic recoil pressure

Po - Ambient pressure

Lines indicate interdependency forces acting on airways

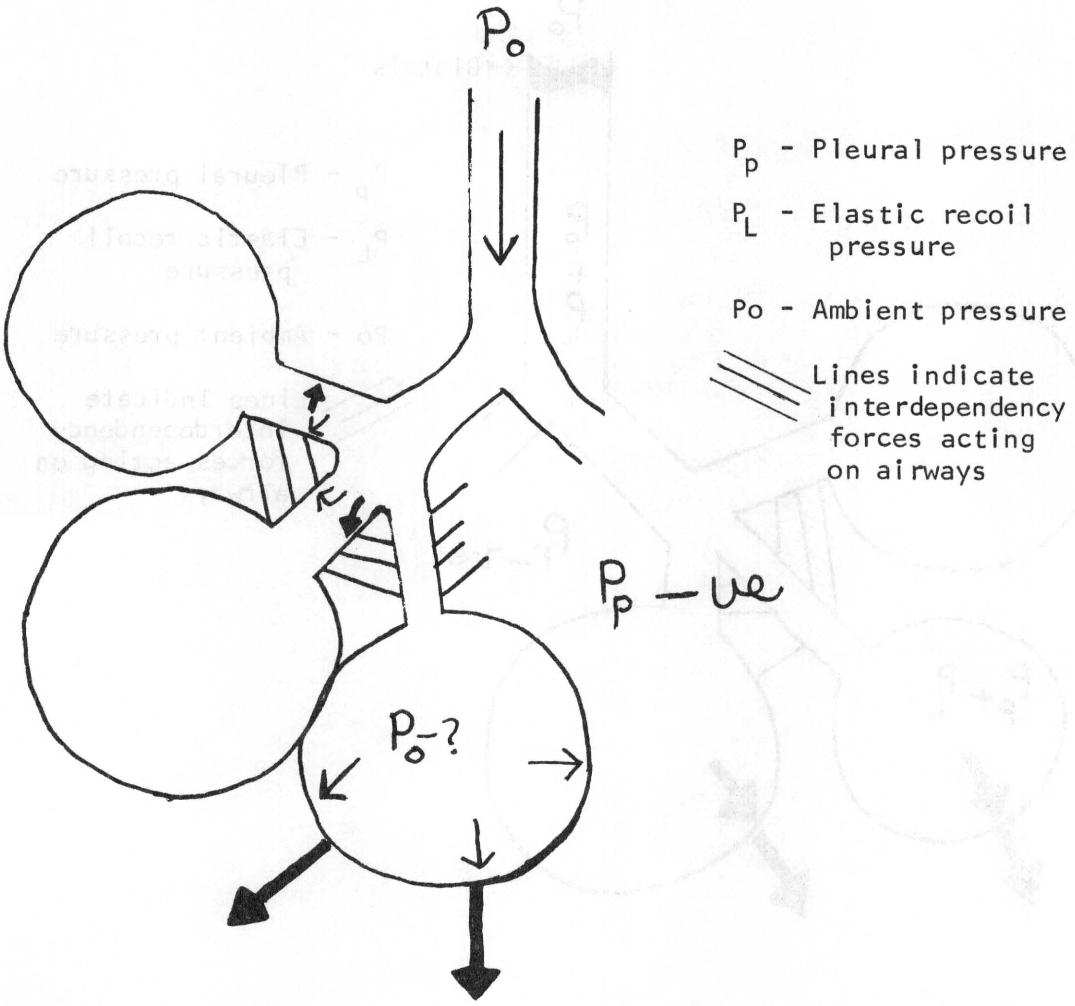
Represents situation during ascent with closed glottis (assuming critical ratios are not exceeded)

(a) P_p is not as great and usually -ve

(b) Interdependency forces are acting to pull airway open.

(c) No flow exists so dynamic stresses on airway do not exist.

Diagram 2



Represents situation during attempted inspiration while ascending.

(a) P_p is very -ve encouraging airway opening

(b) Interdependency forces grow as lung expands

(c) Gas flow resistance is lowered due to increasing airway diameter

Diagram 3

SECTION III

ADDITIONAL PAPERS

These papers are pertinent and have therefore been included; they were not presented at the workshop.

INTRODUCTION TO SCUBA DIVING

(J. Sports Med. Vol. 11 Sept-Oct 1974 pp. 276-290)

A. R. Behnke and L. F. Austin

It is apparent that maximal expiratory effort to residual or near-residual volume, coupled with hydrostatic compression of the lower lobes of the lungs and shift of blood into the thorax, could result in trapping of potentially dangerous volumes of air. During rapid ascent, overexpansion of the trapped air could produce emphysema of lung tissue and embolization of vasculature.

The serious import of these findings will receive some confirmation from the following statements. Heretofore, as a prime defense against air embolization incident to generalized pulmonary overinflation, emphasis has been entirely on continuous exhalation to minimize lung volume during rapid ascent. This was satisfactory when trainees were exhaling against the positive pressure in the Momsen 'lung' (i.e., measured as the hydrostatic column from mouthpiece to relief flutter valve at the bottom of the breathing bag). On the other hand, during 'free' ascent or with scuba gear, maximal expiratory effort could lead to reduced intra-bronchial pressure and consequent airway collapse. Lanphier (19) cites the following, "According to Captain G. F. Bond (personal communication), more than 90 per cent of air embolism cases in submarine escape training after adoption of buoyant-assisted ascent occurred in apparently normal ascents without evidence of pulmonary pathology on subsequent study. Four such men were later put through escape training without incident." In 'free' ascent, therefore, or with scuba gear, one should exhale during ascent from the 'top' of the lungs, so to speak, rather than from the 'bottom' of the lungs. The following fatal case of multiple embolization is best explained by expansion of trapped air as a result presumably of 'over-deflation' during the initial phase of ascent.

Case example. The trainee in submarine escape was an experienced diver who previously had made 20 to 25 free ascents at depths up to 50 feet. On the day of fatal ascent, the trainee left the 100-foot lock and the instructor at that depth gave him a shove upward to accelerate ascent. At 90 feet, the trainee was observed to exhale and he continued slowly upward with 'dog-paddling' motion of arms and legs. At a depth of 50 feet, the instructor at this level gave the trainee another boost upward. At 40 feet, the trainee released a large amount of air and stiffened perceptibly. At 35 feet, the instructor at that level observed that the trainee was unconscious. He was recompressed immediately in the dry chamber but failed to regain consciousness and was pronounced dead at the 100-foot equivalent level.

Autopsy revealed extensive embolization and areas of hemorrhage and laceration in the lower and middle lobes of the lungs.

Comment: At the time (1954), localized overdistention of lung units was not a consideration and the Medical Officer's statement is pertinent. "Here (i.e., in this case) the ascent was <u>too slow</u>, which would indicate an excessive rate of exhalation - the one act which would prevent or militate heavily against the possibility of air embolism."

ADVANTAGES AND DISADVANTAGES OF FREE ASCENT TRAINING

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Since the advent of formal Scuba training, it has been common practice among instructors and organizations to require that the student make an emergency ascent in the open water without breathing through his regulator, in order to receive his certification card. This demonstration of competence in emergency ascent has usually been demanded during the first open water check-out dive. Ascending without properly functioning breathing gear is inherently dangerous, as attested by the stress placed upon this aspect of Scuba training. Air embolism, pneumomediastinum and/or pneumothorax are the consequences to be feared if emergency ascent is carried out improperly, and for this reason a disproportionate amount of classroom and pool time is properly devoted to the subject.

I advocate that free ascent, emergency swimming ascent, buoyant ascent or any means of direct ascent to the surface where the regulator is not used be abandoned as part of any formal course in Scuba training, with particular reference to the novice or basic student. Arguments on both sides of the issue have merit.

The opponents of free ascent training argue as follows: Even the U.S. Navy does not teach free ascent or buoyant ascent under any conditions unless there is a chamber with 165-foot capability immediately available topside with a submarine and diving qualified medical officer in attendance, along with a diving medical corpsman. The Navy puts 8 to 9 thousand men a year through the submarine escape training tower in New London to teach them submarine escape using buoyant ascent, and requalifies an additional large number of men each year at the Pearl Harbor Escape Tower. The casualty rate under these circumstances is low, but there have been fatalities despite the precautions mentioned above and the presence of several instructors in the crystal-clear, warm water of the escape tower. Under certain circumstances the Navy may train men in the absence of some of the safety features described but these instances are rare and always carry with them a specific tactical or training requirement for highly qualified professionals. These professionals know well the risks they take and accept them as being a part of earning their living.

Contrast these ideal conditions with the situation commonly found in civilian Scuba instruction: A suburban housewife has taken up Scuba training only to be able to participate with her husband in a Scuba diving vacation in the Carribean. She receives the basic course of instruction in a swimming pool. At the conclusion of this she may be only marginally at ease under water and marginally familiar with her equipment. She is then asked to don a wet suit (often for the first time) and is taken into a murky, cold quarry to demonstrate her ability to use Scuba gear in "open water." At the end of this demonstration she is asked to make a free, buoyant or swimming ascent from 15 or 50 feet.

Should she embolize and subsequently be crippled or die, the attornies for the claimant and/or her estate and children may very well ask these embarrassing questions: At the time of the accident, where was your qualified diving physician? Where was your topside chamber? Where were your extra instructors in the water? What arrangements had been made to remove this lady to a decompression facility? This would then be followed by the statement: "Even the U.S. Navy does not permit this kind of training, even in circumstances where the trainee is a qualified professional." Free ascent training under these conditions might be likened to checking into a wooden frame hotel where 3 disastrous fires have occurred within the past few months, killing 3 people. The hotel has no fire escapes. However, on reaching your room, you notice it has a balcony overlooking a concrete courtyard into which is sunk a small swimming pool. Since you are planning on going swimming before dinner anyway, and are already wearing a swim suit, would not a reasonable and prudent man carefully estimate the distance to the swimming pool and make a practice jump from the 2nd floor just to be sure his escape route were valid?

The proponents of free ascent training argue as follows: It may be very true that the U.S. Navy observes all of the safety precautions you have described, doctor, but it must be remembered that they have millions of dollars in equipment and operational money to spend on this problem. The Navy should climb down off its high and mighty horse and come out in the real world to face life as it actually is. NAUI, PADI, and other organized instructor groups have a moral obligation to see to it that their students can recover safely from an out-of-air or other emergency situation on the bottom. The American public will go Scuba diving whether we like it or not and whether we train divers or not. Therefore it is incumbent on us as a part of training divers to give them the opportunity to learn how to escape the emergency situation.

Additionally, is not ditch-and-don training given in the swimming pool nothing but free ascent? Can someone not be as easily embolized in 8 feet of water as he can in 50? Doesn't even the U.S. Navy practice ditch-and-don training without the presence of a decompression chamber at pool side? We cannot in good conscience sign our names to someone's certification card knowing full well that he has had no training in a means of leaving the bottom in an emergency; under such circumstances this could very much be akin to signing someone's death warrant. If you prohibit free ascent training you are going to prohibit one of the most vital parts of the entire training program. Instructors by and large are knowledgeable, competent and extremely cautious in teaching free ascent and each student is watched and controlled individually during his demonstration of this. Is it not better to practice this under non-emergency conditions so that the diver will be able to do it instinctively when other factors in an emergency may be distracting him? The risk may be there, but you must admit this risk is extremely small, and the benefits of free ascent training far outweigh the risks.

Which of these points of view is correct or practical? Should a compromise be sought?

Yes, ditch-and-don training must be continued even in the absence of an immediately available decompression facility, as it simply must be taught to all people taking Scuba. When properly done in a shallow swimming pool, the risk is indeed minimal. In the pool, under controlled conditions and the watchful eye of an instructor, the student can be taught to become at ease under water and not to panic if his mask is suddenly knocked off or his air supply ceases. The key to successful emergency ascent from the bottom lies not in actually carrying out the ascent in open water, but being sufficiently relaxed in the water to simply do what is natural, i.e., exhale.

To demonstrate this point, Dr. Charles Shilling, who was supervisor of Submarine Escape Training at the New London Escape Tower in the 1940's, took a mongrel dog to 100 feet in the roving bell and threw him out into the water. Dr. Shilling reports that the dog swam toward the surface, exhaling all the way, as he followed behind in the roving bell. The dog performed beautifully with no previous escape training, did not embolize, and remained Dr. Shilling's pet for many months. (Admittedly the dog had been supplied by Harvard University, so he may have been smarter than some.)

I think that Glen Egstrom and myself are also cases in point. Back in the early days before commercial Scuba gear was readily available, Glen tells me that using the homemade lash-up rig he had built, he invariably experienced equipment failure under water so that free or swimming ascent became his normal mode of surfacing. He never embolized. I began diving in 1950 and did not hear about air embolism until 1953. Nevertheless, while underwater I frequently experienced equipment failures, and failures with surface-supplied gear. I never embolized. Apparently what was important in the case of both Glen and myself was that we were fortunate enough not to have panicked and apparently under the circumstances were able to do what was natural, i.e., exhale on the way to the surface as did Dr. Shilling's dog. Later on, even though I had completed submarine training which included buoyant ascent with the standard life jacket as well as the Steinke hood, I admit that I was extremely uneasy about performing free ascent without a life jacket, which was required to qualify as escape training tower doctor. Under those circumstances, I was not as relaxed and at ease as I would have been if something else had gone wrong and I was simply forced to head for the surface. Navy statistics document that the morbidity and mortality of free ascent is much greater than that of buoyant ascent training, and this is why the Navy abandoned free ascent training except for the escape tower personnel.

Getting back to the question of what kind of training should be provided, I strongly support Glen Egstrom's statement that no diver should dive deeper than he can successfully swim horizontally under water while holding his breath.

If training is to be given in <u>controlled exhalation</u> while moving through the water, I advocate the "horizontal hum technique". In this situation one has the student submerge at the deep end of the pool breathing through his regulator and then after having taken a full breath he removes or doesn't remove the regulator from his mouth and swims along the bottom of the pool toward the shallow end, humming continuously as he goes. He continues this until he runs out of air or reaches the shallow end of the pool.

In summary I would recommend the following:

1. The teaching of free, swimming, or buoyant emergency ascent be abandoned in the training of civilian Scuba divers unless there is a chamber immediately available topside and a qualified diving physician is present with adequate equipment.

2. Greater emphasis be placed on making the student feel at ease under water through intensive pool training, where his mask is flooded, his air is shut off and other simulated emergencies are carried out.

3. Controlled exhalation be practiced using the "horizontal hum technique".

I have treated two air embolism casualties in Scuba divers in the last five years. The first was during training in free ascent as part of the check-out dive, and the other case was unrelated to an emergency in that the patient unknowingly ascended while doing the Valsalva maneuver in an attempt to clear his ears. Dr. Nemiroff of Ann Arbor, Michigan has treated three cases of air embolism in Scuba divers, all stemming from the training situation. It would appear that we may treat more cases of air embolism in decompression chambers due to training than we treat cases related to actual emergencies. It is rare indeed to find an instructor who continues to teach free ascent in the open water after having had one of his students embolize.

A good point to bear in mind is that there are a great number of ex-Navy diving medical officers who probably could be persuaded by a claimant's attorney to take the stand in favor of the claimant should such an occasion arise.

FREE ASCENT TRAINING

John Knight

I have been asked to contribute an article on Free Ascent giving the Royal Australian Navy (RAN) view. I cannot give an "official" view, but offer my personal interpretations of current RAN practice and the reasons for that practice.

Because of past fatalities, the RAN attitude is that Free Ascent training can only be carried out adjacent to a chamber. The RAN considers that, although with proper diving procedures there should be no need for free ascents, a properly trained diver should know how to do one and keep in practice. In fact, RAN free ascent training is really buoyant ascent training, since apparatus and weights are ditched and the sailor is helped up by the buoyancy of his wet suit. The ascent rate aimed at is the standard 60 feet per minute.

Some years ago there were deaths during free ascent training. At least one man died while being carried unconscious along the jetty to the recompression chamber. Following this, free ascent training was only carried out when a portable recompression chamber, with a medical officer standing beside it, was on the jetty at the point where the trainees would surface. Unfortunately, the portable recompression chambers are one-man deck decompression chambers designed for the uncomplicated decompression of a fit diver. The decompression technique they were designed for involves the diver in an ascent (at 60 feet a minute) to the surface, immediate entry into the deck decompression chamber, and immediate pressurization to 10 meters deeper than the depth of his first stop. He must reach this pressure within five minutes of leaving the bottom. After five minutes at this depth, decompression is carried out as for a bottom time of 10 minutes longer than it actually was. For what they were designed to do, these chambers are excellent. But they are not treatment chambers. They can hold two men but the second has to lie beside or on top of the first and cannot act as an efficient attendant. There is no room for any resuscitation. Once the patient is inside, there is no way that anyone can get at him. If he vomits and inhales his vomit, the chamber becomes his coffin. A further drawback is that the one-man deck decompression chambers were made over 20 years ago when the idea of mating small and large chambers for transfer under pressure was unthought of, so there is no way of transferring the patient to the larger RAN chamber where he can have an attendant and be resuscitated if necessary. The RAN is obtaining new chambers, both fixed and portable, with transfer-under-pressure capabilities which will allow for immediate treatment at the jetty edge and transfer to the larger chamber.

Recently the RAN appears to have reduced compressed-air free ascent training and taken to training in free ascent using oxygen breathing apparatus. While this still puts the lungs at risk, the embolus is inherently less dangerous because the oxygen will all be metabolized and the bubble will disappear in the process, allowing restoration of blood flow. The problems of the single-man chamber have probably played a part in this decision. The current practice is to have a medical sailor with resuscitation equipment and a stretcher at the site of training on the jetty close to the large recompression chamber. The training party is large enough to provide at least four stretcher bearers. A doctor is in attendance at the School of Underwater Medicine, less than 20 feet from the chamber. While this system does increase the delay in recompressing the man by a minute, the payoff is better care under pressure.

FREE ASCENTS: A VIEW FROM THE SCOTTISH SUB-AQUA CLUB

A.S.G. Curtis

I have been asked by Dr. D. Walker to write a defence of the practice of free ascents in the training used by the Scottish Sub-Aqua Club (SSAC).

Speaking purely personally for a paragraph, I would remark that I have been surprised at the intense and righteous disapproval that some people have evinced on hearing about our use of free ascents. It seems to me that as soon as we have a perfect knowledge about how we should dive and train it will be time to start throwing stones at those who are clearly amongst the imperfect. We are not at that happy state yet and the SSAC regards its present practices as the best it knows, but is quite aware that in the future both the accumulation of evidence and of thought is bound to alter at least some if not all of our training. Thus the views expressed in this article represent the present and the historical position but cannot be held to be a statement of what we may do in the future.

First, what do we do? SSAC training and testing is not greatly different from CMAS or even from BSAC training. The stages which a trainee should pass through are Snorkel Diver, 3rd Class Diver, 2nd Class Diver, and then onwards to 1st Class Diver and/or a variety of instructional qualifications. During the open-water tests for the 2nd Class award the trainee, who by now will have at least 20 and probably more than 30 open-water dives to his or her credit, is asked to complete, after appropriate training, a test in which a slow (1 meter per 3 seconds) free ascent in a non-buoyant state from 6 or 7 meters' depth to the surface is performed. Why do we do it? Basically for three reasons:

1. Free ascent situations will occur, however careful we are about matters like equipment servicing, dive planning, and avoidance of situations that might lead to free ascent. After all, a great deal of training is directed towards situations which never ought to happen, e.g., rescuing someone else. In recent years, as well as earlier, at least 16 incidents per 10,000 dives have occurred in the SSAC in which such events as equipment failure, air supply exhaustion, rescue of panicking divers, and very occasionally unforeseen difficulties in handling potentially buoyant articles on wrecks, etc., have led to the necessity of making free ascents. Similar incidents have occurred in other clubs.

2. Our training philosophy is that training is mainly towards meeting potential emergencies and that it should be practical rather than purely theoretical. In other words it is better to have some practical experience of one's ability to cope with a potential emergency situation (simulated in training) rather than a purely theoretical knowledge, because this gives greater insight and confidence as well as proven ability, provided that the risk in training is appreciably smaller than the risk in not being practically trained. We should also look at the likelihood of a situation arising and thus determine whether the training should be given to every diver or only to those who have both more experience and more probability of carrying out a large number of dives and thus of encountering the situation. We also need to analyze each situation and the appropriate response(s) and consider at what point, taking into account other practical and theoretical knowledge required, the training should be introduced.

3. At this point we enter an area where information is partially lacking. Nevertheless it is clear that practicing free ascents as we do it (see below) must have a fairly small risk. The Scottish Sub-Aqua Club has now completed more than 2800 free ascents without incident since the practice was re-introduced. It can be argued that perhaps a very small amount of barotrauma might have been detectable shortly after the ascents but there is no evidence from which to suppose that this was so.

The Club is in the process of introducing a regular requirement for repeat medical examinations for divers and those (admittedly few) divers who have been re-examined after undertaking free ascents and have shown signs of lung damage.

Are free ascent accidents more frequent in those clubs that ban their practice? We do not know as yet, but we do know that incidents requiring free ascent do occur during dives. Evidence on the incidence of various types of accident in the SSAC is set out below. These data were collected in a recent survey. Basically, these data tell us that air failure is a far commoner incident than decompression sickness, or hypothermia, or unexpected sickness unconnected with diving manifesting itself during a dive.

It is worth looking at the events and arguments that led the Royal Navy (RN) to suggest that free ascent training should be banned. In the late 60's and early 70's, the RN had a small number of cases of fatal barotrauma during submarine escape training, mainly amongst the trainees. The training requires the use of a very fast, highly buoyant ascent with speed of 2 meters per second or faster, with buoyancy in excess of 10 kilograms. Clearly these very fast ascents do have a relatively high risk of barotrauma, perhaps particularly amongst those who have little or no previous experience of being under water. It can be pointed out that the nearest equivalent situation for the amateur diver arises either during ABLJ training, in which mismanagement can lead to highly buoyant ascents, or when weight belts are lost, particularly by those who have inflated dry suits or who carry a great deal of weight. If free ascent poses a great risk to the amateur diver, we should perhaps consider banning ABLJ training or the use of inflatable dry suits.

Surprisingly, the RN does not have appeared to have carried out any detailed research into the incidence of free ascent barotrauma amongst amateur divers in arriving at its recommendations and may not have been aware of the type of training that was in fact being used. In the SSAC, the emphasis is first that would-be divers should receive whole plate X-ray examination to ensure that they are free from bullae. When practical training starts, the trainee starts working on a shot line, with great care being taken to ensure that he or she is very close to neutral buoyancy. Initially the trainee is accustomed to use a shot line for ascent, finning to ascend. Then the trainee works on the line, ascending with his mouthpiece out but close to hand should the need for it be felt, breathing out and with an instructor by his side. When free ascents can be done from 6-7 meters at the correct speed on the shot line, the trainee then repeats this free from the shot. Free ascents from depths in excess of 7 meters do not form part of SSAC training.

Thus, though we recognize that free ascent does carry some potential risk, there is a very low risk of consequent barotrauma, so low that in fact it has not been seen in SSAC. All training and diving procedures carry a measure of risk: for instance there have been at least three cases of incipient drowning in the pool during SSAC training, happily obviated by watchful and knowledgable instructors. But it is clear that the incidence of the need to carry out free ascents is very much higher, however avoidable they might have been in a more perfect world. However, the SSAC regards free ascent as the solution of last remedy to an air supply failure, which should be solved preferably by making use of a companion's octopus rig, then by breathing from an ABLJ, then by a shared ascent and, as a last resort, by free ascent.

The evidence we have allows us to answer two of the three important questions which follow, and which sum up the whole question.

1. Do situations leading to free ascent occur with sufficient frequency to require training for this form of ascent? An incidence of one free ascent per 243 dives (about 6 years' diving for the average SSAC member) suggests to us that since free ascent is the fifth most common diving incident it is well worth training for it, provided that the answer to the next question is suitable.

2. Is there an appreciable incidence of risk in free ascent training? The answer to this is that since no incident has occurred during

the 2800-odd training ascents, it must probably be a very low risk.

3. At this point all we can conclude is that there is little risk in free ascent training and that it trains for a fairly frequent incident. However, it might be the case that trained divers who have not received free ascent training also cope just as well with free ascents as those who are trained, so we need to ask: Is there appreciable risk in not being trained for free ascent?

The SSAC cannot answer this, but we await with interest data from other clubs that do not carry out free ascent training. It should be remembered that the reasons which lead a particular diver to choose to carry out a free ascent may represent failure of reasonable maintenance of equipment, pre- or in-dive checks, misjudgment of situations and incorrect thought at the moment of accident, all of which can be reduced in incidence by better training, but that it is impossible to eliminate such human failings entirely. We plan to carry out a larger, more thorough survey amongst our members to discover if the frequency of free ascent is related to duration of experience, and whether it is commoner in our earlier trainees than in our most recent trainees.