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SPUMS JOURNAL

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South Pacific Underwater Medicine Society Incorporated

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SPUMS ANNUAL SCIENTIFIC MEETING 1992

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OBJECTS OF THE SOCIETY

To promote and facilitate the study of all aspects of underwater and hyperbaric medicine.
To provide information on underwater and hyperbaric medicine.
To publish a journal.
To convene members of the Society annually at a scientific conference.

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The preferred length of original articles is 2,500 words or less. Inclusion of more than 5 authors requires justification. Original articles should include a title page, giving the title of the paper and the first names and surnames of the authors, an abstract of no more than 200 words and be subdivided into Introduction, Methods, Results, Discussion and References. After the references the authors should provide their initials and surnames, their qualifications, and the positions held when doing the work being reported. One author should be identified as correspondent for the Editor and for readers of the Journal. The full current postal address of each author, with the telephone and facsimile numbers of the corresponding author, should be supplied with the contribution. No more than 20 references per major article will be accepted. Acknowledgements should be brief.

Abstracts are also required for all case reports and reviews. Letters to the Editor should not exceed 400 words (including references which should be limited to 5 per letter). Accuracy of the references is the responsibility of authors.

References

The Journal reference style is the "Vancouver" style, printed in the Medical Journal of Australia, February 15, 1988; 148: 189-194. In this references appear in the text as superscript numbers.[1-2] The references are numbered in order of quoting. Index Medicus abbreviations for journal names are to be used. Examples of the format for quoting journals and books are given below.

1 Anderson T. RAN medical officers' training in underwater medicine. *SPUMS J* 1985; 15 (2): 19-22
2 Lippmann J and Bugg S. *The diving emergency handbook*. Melbourne: J.L.Publications, 1985: 17-23

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DAN Europe FITNESS STANDARDS FOR RECREATIONAL DIVERS and RECREATIONAL DIVER'S FITNESS LOGBOOK

DAN Europe has added the above topics to the **Medical standards for divers conference** to be held in Edinburgh, Scotland, from 8th-11th March 1994.

The potential requirement for professional dive guides and sports diving instructors to pass the same annual medical examination as other working divers will be addressed. The extra session, on Tuesday March 8th, will also review such problems as the asthmatic diver, the diabetic diver and the physically handicapped diver.

The recreational diving session will be free to those registered for the main meeting. See notice on page 144.

For further information contact
Biomedical Seminars,
7 Lyncroft Gardens,
Ewell, Surrey KT17 1UR, UK.
Fax ISD-44-81-788 7036

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PROJECT STICKYBEAK

This project is an ongoing investigation seeking to document all types and severities of diving- related accidents. Information, all of which is treated as being **CONFIDENTIAL** in regards to identifying details, is utilised in reports and case reports on non-fatal cases. Such reports can be freely used by any interested person or organisation to increase diving safety through better awareness of critical factors.

Information may be sent (in confidence) to:
Dr D. Walker
P.O. Box 120, Narrabeen, N.S.W. 2101.

The Editor's Offering

A new author, Michal Kluger provides evidence that divers are being successfully educated to consider all after diving problems to be dive related. Many of us overlook the chance that an ordinary medical problem could occur when we are diving. We expect to find diving related problems. How many of us would have thought of atrial fibrillation as the explanation of a diver's malaise and breathlessness ?

Professor Otto Molvær, from Bergen in Norway, has been contributing papers to the SPUMS Journal for many years. Like Carl Edmonds he attended the meeting at Godøysund earlier in the year and has provided a less racy description of the meeting. There are always two views of any story.

Jeff Wilks provides two Queensland views, one of the costs diving medicals. It interesting to see the price of a diving medical from a fresh viewpoint. His other view is of the effectiveness of diving safety research which is carried out by "outsiders". We all know that we are the only ones who understand our job, otherwise someone else would be doing it. But in the real world, where everyone is suspicious, and often rightly so, of those from "outside" it is worth remembering that we grow our own blinkers and shut our eyes to inconvenient facts that others can see clearly. When research focuses on safety one expects that it will be welcomed by those interrogated. But when they feel threatened by the questions are they likely to be forthcoming ? Trust is a fragile plant, and Jeff has nurtured the fields of diving safety research to produce good crops of information. One hopes that his foretelling of disappointment in Cairns in 1994 does not eventuate.

The vast majority of this issue (35 pages) is devoted to the Workshop on emergency ascent training and the events leading up to it. In every walk of life there is an accepted path that the majority strolls along. People who suggest alternatives are sometimes unwelcome stirrers. The three papers by Dr G (or GD or GAD) Harpur of Tobermory in Ontario, Canada, have coloured the thinking of your editor and his predecessor for the past 15 years. So it is no surprise that they appear as hors d'ouvres before the banquet. We had letters from Ireland, England, the United States and South Australia putting forward different views.

Drew Richardson of PADI, spoke on behalf of the American National Scuba Training Council explaining why and how the training agencies carry out emergency ascent training. He came down in favour of octopus breathing as the primary dependent rescue method. The American expression "alternate air source" has been changed in the two Richardson papers to "alternative air source" because nobody breathes alternately from their own regulator and the buddy's octopus throughout the dive. Anyone who dives knows that many buddies are only in the same ocean, certainly not close enough to touch when one needs the octopus. So trainees are taught to make an emergency (controlled) swimming ascent, which is the recommended independent method.

Chris Acott shows, from DIMS data, that slow ascents are unlikely to cause harm, but rapid ascents are. If you are going to do a rapid ascent the safest way is to use your buddy's octopus or a SPARE AIR (alternative source) and the most dangerous is to buddy breathe your way up. Richardson and Cummins provided the most valuable paper in the meeting, really new data about the incidence of problems and deaths during PADI training for emergency ascent the world over. Because PADI instructors have to report incidents within a specified time to conform to PADI standards, and to be covered by their professional insurance, these figures can be accepted as reliable. The are a vast improvement on the Naval figures from submarine escape training towers (SETT), but then the sailors come up at around 100 m a minute, speeds which few sports divers achieve.

The final paper, provided by the Editor, includes some SETT details and makes a plea that all training should be dictated by the need for the diver who is out of air to reach the surface. If the diver fails to achieve this someone is going to be explaining things to the coroner and all the training is in vain.

The Workshop papers close with a review by the Co-Chairmen of the papers and discussions which led to the new SPUMS policy, which is printed on page 139

We would draw your attention to the conference in Edinburgh in March 1994 where the medical standards for occupational and recreational divers will be discussed. The organisers are Biomedical Seminars for which one can substitute David Elliott (of Bennett and Elliott) who was our guest at the 1993 Annual Scientific Meeting. It will be an excellent and useful meeting.

We close with an apology. In the last issue the Editor's report to the Annual General Meeting foreshadowed an index for the Journal from the first issue in 1971 to the end of 1992 would be mailed with this issue. Circumstances, largely computer upgrading which left the data base program an unloved orphan, have slowed production and the index is not ready. However we have found a Mac foster mother to love the child and growth is again progressing nicely.

ORIGINAL ARTICLES

ATRIAL FIBRILLATION PRESENTING AS DECOMPRESSION ILLNESS (DCI)

Michal Kluger

Summary

Early hyperbaric treatment to prevent long term sequelae of decompression illness (DCI) following scuba diving is established treatment. Diving related problems in general are now being increasingly recognised by both scuba divers and medical practitioners. However it should not be forgotten that divers may have non-diving related pathology which may manifest itself while scuba diving. The following case was referred to a hyperbaric facility as DCI but proved to be cardiac related. The significance of cardiac disease among divers is discussed.

Case Report

A previously well 47 year old male diver with 25 years of scuba diving experience was referred for hyperbaric treatment, with a presumed diagnosis of DCI, following the sudden onset of breathlessnesss, lethargy, unsteadiness, dizziness and chest discomfort following a scuba dive. The diver dropped his underwater camera while on the surface before his dive. Sea conditions were calm with a water temperature of around 17°C. Although wearing full scuba gear he performed a breath-hold dive to approximately 7 m and retrieved his camera. Almost immediately on surfacing he felt very short of breath and extremely unwell. This feeling resolved after several minutes and the diver started his scuba dive. He descended to 22 m, but again felt unwell and extremely tired almost immediately after descent. After 15 minutes at this depth he decided to surface due to this feeling of general unwellness. During the ascent, which was slow and controlled, he developed increasing shortness of breath associated with chest discomfort. This worsened while getting into the boat, where he also experienced a feeling of unsteadiness and lightheadedness. The diver at the time noted his heart to be racing, approximately 180 beats a minute. On admission to hospital at 1300 hours he was pale and sweaty. He had a radial pulse rate of 130 beats a minute with an apex rate of 170 beats a minute. Recumbent blood pressure was 110/80 mm Hg. Heart sounds were normal and no murmurs were present. His chest was clear with no evidence of aspiration or pulmonary oedema and there was no subcutaneous emphysema. Examination of the CNS showed the diver to be alert and orientated. Serial 7's were complete in 40s with one mistake. Three number recall and short term memory for phrases were normal. Cerebellar and cranial nerve examination was also normal. Sharpened Romberg test was normal, 50\60 right, 60\60 left. ECG showed atrial fibrillation with a ventricular rate of 170 beats a minute. Chest X-ray was normal.

Although the symptoms following the scuba dive suggested a diagnosis of DCI or cerebral arterial gas embolism (CAGE), the onset of symptoms after the initial breathhold dive and again at depth made such diagnoses unlikely. Following careful examination, it was judged that the cause of the diver's signs and symptoms were primarily myocardial, but precipitated by the initial breathhold dive. He was given 500 mcg of digoxin intravenously after which his heart rate slowed and he reverted to sinus rhythm.

Further questioning revealed that he had had two previous episodes of palpitations, one of which was associated with a breathhold dive 5 years earlier. On that occasion he had dived into a heated swimming pool to retrieve some coins from the bottom. On surfacing he felt excessively tired, slightly short of breath and had noted his heart to be racing. This was self limiting, lasting for approximately 45 minutes. A similar episode 2 years previously, not associated with diving, led his general practitioner to start him on a beta-adrenoceptor antagonist. This however the patient stopped taking it. Both the diver's parents had a history of ischaemic heart disease.

Following control of his atrial fibrillation he was reviewed by a cardiologist. Investigations included an echocardiogram, exercise ECG, complete blood count, biochemistry, thyroid function tests and cardiac enzymes, all of which were normal. A diagnosis of paroxysmal atrial fibrillation was made and he has been advised to refrain from scuba diving for 12 months, and then to have a full diving medical review by a specialist in diving medicine.

Discussion

Although the occurence of DCI and CAGE are well documented and have a high profile in the diving community, they account for only a small number of deaths associated with scuba diving. In a recent survey of causes of death of divers in Australia and New Zealand, 13% of fatalities were associated with pulmonary barotrauma, 12% of deaths were due to cardiac disease while there were none associated with decompression illness.[1] When the fatalities were examined for contributing causes, the incidence of cardiac disease among diving fatalities approached 21%. This group consisted of divers who had a mean age of 43.6 and died suddenly either at the beginning or end of a dive. Moreover, recent data from the Divers Alert Network (DAN USA) has shown comparable figures for the incidence of cardiac disease and diving related mortality in the United States.[2]

The onset of our diver's symptoms was immediately following his first breath-hold dive. Although pulmonary barotrauma has been identified following breath-hold diving,[3] this is rare and was not identified in this case. The diver did not complain of a faulty regulator, and the lack of chest X-ray changes and of pyrexia make a diagnosis of salt water aspiration improbable. DCI is unlikely after breathhold diving, and does not usually present while at depth. Although pulmonary oedema following scuba diving has been described it usually presents with productive frothy sputum and abnormal radiological signs.[4]

While dysrhthymias have been reported during breath-hold diving, these are usually bradycardias or junctional rhythms.[5,6] Indeed the combination of facial immersion in cold water with maximal inspiratory breath-hold have been implicated in the augmentation of the diving reflex in man.[7] This has been used in clinical practice to terminate supraventricular tachycardia. Data is limited in humans regarding the rhythm changes seen during recreational scuba diving. McDonough reported self-limiting supraventricular tachycardias in divers during recreational dives in cold waters,[8] while asymptomatic ventricular fibrillation has been reported in a commercial diver during a training dive.[9] Factors important in initiating these dysrhythmias may include water temperature, anxiety level, effort during the dive and pre-existing cardiac pathology. Increased central blood volume secondary to body immersion causing raised right sided filling pressures resulting in stretching of atrial stretch receptors. This may be of importance in the initiation of such supraventricular rhythm problems. A further possibility is that the diver had in fact been in atrial fibrillation before the initial breath-hold dive. The combination of tachycardia combined with a sustained Valsalva manoeuvre impeding venous return could have led to a significant decrease in cardiac output, resulting in the diver's symptoms of extreme tiredness and malaise.

A study which looked at forearm vascular resistance in divers with a history of diving induced pulmonary oedema concluded that a pathological increase in vascular resistance occurred in an idiosyncratic fashion following exposure to cold.[10] As most of the divers with abnormal vascular reactivity developed hypertension later in life, this may be an important aetiological factor in its development. However studies which look at the prevalence of cardiac disease in the diving community and how diving affects divers under certain situations, e.g. deep diving, wreck, cave diving and during training, are lacking . It is known that novice parachutists have a dramatic cardiovascular response to their first jump, with heart rates of around 170 beats a minute occurring,[11] however there is no data on this aspect of scuba diving in the literature. This may have significance in those novice divers with known cardiovascular pathology or those at high risk e.g. strong family history of ischaemic heart disease, smokers and those with increased serum cholesterol.

As the Australian and New Zealand Study has indicated, at least 25% of divers who died were medically unfit.[1] This emphasises the need for physicians qualified in diving medicine to perform medicals on all prospective diving candidates and also raises the question of the need for certified recreational divers to have regular medical examinations to ascertain continued fitness to dive, similar to those involved in commercial diving.

Finally the question whether to allow this diver to return to scuba diving is debatable. The various investigations have shown no identifiable structural or metabolic reason for his dysrhythmia. The conseqences of this were mild and on one ocasion self terminating. However he has now demonstrated repeated episodes of cardiovascular instability, and these may not necessarily be as easily terminated in the future. Moreover by the nature of diving, urgent medical attention may not be possible for many hours or even days.

Conclusions

Cardiac disease may be more common in the recreational diving community than is currently appreciated. This factor, along with the potential for provocation during a dive, makes primary cardiac pathology high on the list of differential diagnoses in the diver who presents with chest pain, shortness of breath and extreme fatigue, symptoms which occur in DCI and CAGE. The diagnosis of a primary diving related pathology can be made only after exclusion of all other causes of the symptoms by a careful history taking and full clinical examination. Further studies are needed to identify more accurately the incidence of known or covert ischaemic heart disease among divers and the effects of scuba diving.

References

1 Edmonds C, Lowry C and Pennefather J. Why divers die; the facts and figures. In *Diving and Subaquatic Medicine, 3rd edition.* Oxford: Butterworth-Heinemann Ltd,1992; 80-94

2 Mebane GY, Lew N and Dovenberger J. Review of autopsies on recreational scuba diver 1989-1992. *Undersea and Hyperbaric Med* 1993; 20 (supp):50

3 Kol S, Weisz G and Melamed Y. Pulmonary barotrauma after a free ascent- a possible mechanism. *Aviation, Space and Environmental Med* 1993; 64: 236-237

4 Wilmshurst PT, Nuri M, Crowther A, Betts JC and Webb-Peploe MM. Recurrent pulmonary oedema in scuba divers; prodrome of hypertension: a new

syndrome. In; Bacharach A.J., Matzen M.M., eds. *Underwater physiology VIII.* Bethesda: Undersea Medicine Society, 1984: 327-339

5 Ferrigno M, Grassi B, Ferretti G, Costa M, Marconi C, Cerretelli P and Lungren C. Electrocardiogram during deep breath-hold dives by elite divers. *Undersea Biomedical Res* 1991; 18 (2): 81-91

6 Campbell LB, Gooden BA and Horowitz JD. Cardiovascular responses to partial and total immersion in man. *J. Physiol* 1969; 202: 239-250

7. Gooden BA. The diving response in clinical medicine. *Aviation Space and Environmental Med* 1982; 53(3): 273-276

8 McDonough JR, Party BS and Saffron RN. Cardiac arrhythmias as a precursor to drowning accidents. In *The physiology of Breathhold Diving.* Eds. Lungren CEG and Ferrigno M. Washington, DC: Undersea and Hyperbaric Medical Society, 1987; 212-228

9 Sem-Jacobsen CW and Styri OB. EKG arrhythmias monitored from free swimming scuba divers at various depths. *Proc.J Inter Hyperbarie et Physiologie Subaquatique.* Marseilles June 8-11 1970; 130-136

10 Wilmshurst PT, Nuri M, Crowther A and Webb-Peploe MM. Cold-induced pulmonary oedema in scuba divers and swimmers and subsequent development of hypertension. *Lancet* 1989; (i) 62-65

11 Galante J, Hernandez A, Colin L, Camacho B, Verdejo J and Ferez S. Continuous electrocardiographic recording during a first parachute jump. *Arch Inst Cardiol Mex* 1988; 58(4): 325-331

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THE WORLD AS IT IS

LONG TERM HEALTH OF PROFESSIONAL DIVERS

International Consensus Conference
held at
Godøysund, Norway, 6-10 June 1993

Otto I. Molvær

Ten years ago an international workshop entitled “Long Term Neurological Consequences of Deep Diving”, organised by the European Undersea Biomedical Society (EUBS) and the Norwegian Petroleum Directorate (NPD), took place in Stavanger, Norway. At that time preliminary results from a newly started Norwegian research program on possible long term effects of deep diving on the divers’ health caused enough concern to arrange that workshop.

That time, U.S.A.,U.K., France, Sweden and Norway were represented with 38 invited participants. The views on the subject varied widely, and any attempt made to reach consensus failed.

In his introduction to the proceedings[1] of the conference, the chairman, Professor R.I. McCallum concluded as follows: “In view of the lack of hard evidence of actual neurological damage from deep diving and the need for more data, is there a case for limiting deep diving now? Many feel that deep diving, when properly carried out, is safe and I think it is fair to say that there was little support for limiting such activity at the present time, but rather for intensifying the monitoring of those taking part in it.”

And the monitoring was intensified, including also the pulmonary and auditory functions. The results of our research have been published internationally, and met with scepticism. Nevertheless, this time we optimistically called the convention a ***consensus*** conference in our invitational leaflet, although we knew the subject was controversial.

Now the scope was widened from possible ***neurological*** effects of ***deep*** diving to possible effects on the diver’s ***health*** of professional diving in a broader sense, and in addition to the nations participating in 1983, representatives from Australia, Switzerland and Ukraine were included. Of the 36 persons invited, only two did not show up at all. In addition, the authorities and the oil and diving companies had observers in the conference.

The discussions were lively, to say the least, but since the conference was held in a small island on the Norwegian west coast, no one could escape until some sort of consensus was reached. Naturally, the final statements had to be rather general:

“There is evidence that changes in bone, the central nervous system and the lung can be demonstrated in some divers who have not experienced a diving accident or other established environmental hazard. The changes are in most cases minor and do not influence the diver’s quality of life. However, the changes are of a nature that may influence the diver’s future health.

The scientific evidence is limited and further research is required to obtain more definite answers to the long term effects of diving.”

All plenary speeches and discussions were audiotaped, and transcripts are being made. Eventually, the proceedings will appear as a hard bound book that will be generally available.

Reference

1 Shields TG, Minsaas B, Elliott DH and McCallum RI. *Long term neurological consequences of deep diving.* Proceedings of a workshop organised by the EUBS and the NPD, Stavanger 1983.

Professor Otto I. Molvær works both at NUTEC and the Department of Otolaryngology, University of Bergen. His address is NUTEC, P.O.Box 255, N5034 Ytre Laksevåg, Norway.

The above is an alternative view of the conference reported on by Dr Carl Edmonds in the last issue.

SCUBA DIVING MEDICAL EXAMINATIONS: NUMBERS AND COSTS

Jeffrey Wilks

Introduction

The continuing debate about scuba diving medical examinations has received attention in recent months. Essentially the debate has been about General Practitioners' (GPs) training and qualifications to conduct diving medicals. Some argue that these examinations are specialised, and that only GPs with specific training in underwater medicine should conduct them. In support of this view, a 1985 study of 364 Queensland doctors involved in the assessment, advice or treatment of divers revealed that many were unable to match eight common diving accidents with their major treatments. From the specialists' point of view, there were also a number of important screening tests not routinely performed by GPs in that study.[1]

Until recently, Queensland was the only state in Australia where entry level scuba diving candidates were required to undergo a medical examination prior to using self-contained underwater breathing apparatus (Scuba). This requirement was initially part of the Workplace Health and Safety Act 1989, and is now included in the Code of Practice for Recreational Diving at a Workplace.[2,3]

In other parts of the country divers currently comply with Australian Standard 4005.1 (published by Standards Association of Australia, 16 April, 1992) which also requires a medical examination prior to using scuba equipment as part of entry level certification training.[4] The difference in Queensland is that a "diving medical practitioner" is defined as a "medical practitioner who has completed a course in diving medicine approved by the Board of Censors of the South Pacific Underwater Medicine Society (SPUMS)." Under Australian Standard 4005.1 any registered medical practitioner can perform the diving medical examination, though the Standard does recommend that the doctor be one who has completed an approved course of training. Since this is only a recommendation, many dive centres continue to use medical practitioners who have experience in diving medicine, but may not have attended a formal training program.

At the present time the AMA has adopted the view, in support of Australian Standard 4005.1, that "knowledge and experience" in conducting diving medicals is all that is required from a GP, and while specialised training is desirable, it should not be mandatory.

In a letter outlining the AMA position on diving medicals, Wilkins[5] asked about the numbers of regular or occasional sport scuba divers throughout Australia, and how often did SPUMS believe medical examinations should be performed for them? The actual number of diving medicals that are required in Australia each year has not been discussed before, so the first aim of this paper is to provide the relevant figures.

Australian Divers Requiring a Medical Examination

The majority of diving medical examinations conducted in Australia are for new divers entering training to gain their open water certification. This entry level licence allows them to dive in buddy pairs to a recommended maximum depth of 18 metres, in fair weather conditions, in the area where they were trained. AS 4005.1 recommends that whenever divers encounter a new diving environment they should seek orientation to the new conditions. Since certification cards do not have an expiry date, the current situation is that a recreational diver is only required to have one medical examination to obtain his or her initial licence. There is no requirement for regular check-ups thereafter.

Based on figures provided by the four main Australian scuba training agencies (NASDS, NAUI, PADI, SSI) there were 54,153 new open water certifications issued during 1991. Since all new divers technically require a medical examination, a similar number can be anticipated each year. In addition, there were 19,242 other certifications issued during 1991, ranging from advanced and specialty ratings through to leadership qualifications (eg. divemaster and instructor).[6] Many of these divers may be requested to gain a medical clearance before taking their continuing education course. However, as noted above,

TABLE 1

A COMPARISON OF PRICES FOR RECREATIONAL DIVING MEDICAL EXAMINATIONS

Price ($)	Actually charged by 50 SPUMS members	Thought reasonable by 50 dive shops
20	-	3
25	-	5
28	3	-
30	1	9
35	2	6
36	1	-
40	-	11
45	6	2
50	6	10
55	4	1
57	2	-
60	10	1
64	1	-
65	4	2
70	1	-
75	4	-
80	1	-
90	1	-
100	2	-
150	1	-
Average price (mean)	$59	$39
Most frequent price (mode)	$60	$40

there is no current requirement for regular check-ups of certified recreational divers. The exceptions to this are divemasters and instructors, who, by Queensland legislation, are expected to have an annual medical examination. The estimated number of examinations that would be required in Australia each year is therefore around 75,000.

Price Considerations for Diving Medicals

The second topic that has received virtually no attention in the debate about diving medical examinations is that of price. Consumers are very conscious of the price charged for various goods and services.

In a previous study, the differing views of instructors and certified divers about a "reasonable price" to pay for scuba refresher programs was identified as a major barrier to diver involvement.[7] To determine whether similar discrepancies exist with the price of diving medical examinations a small study was conducted.

To gain information about the prices charged for a recreational diving medical examination a telephone survey was made of 50 randomly selected doctors practising around Australia. The names were taken from the list of doctors who did diving medicals published by SPUMS in 1991.[8]

Table 1 presents the findings of the study. Prices ranged from $28 in Cairns, through to $150 by one doctor in Victoria. The average price for a diving medical examination was $59, while the mode or most frequently charged fee was $60. These prices did not include any specialised tests that may be required beyond the standard diving consultation, which according to AS4005.1 does not necessarily include audiometry, although it is recommended. However it is likely that most of the doctors contacted would include audiometry which is considered necessary by SPUMS.[9]

In contrast, a second telephone survey of 50 Australian recreational diving companies revealed that operators consider $39 to be an acceptable average price for a diving medical examination, with the most frequently suggested fee being $40. The 50 dive operators were randomly selected from advertisements in trade publications, with all states and territories represented.

Discussion

The estimate of about 75,000 diving medical examinations being required each year shows that there is a substantial market for this specialised service. Whether GPs without specific training in underwater medicine can perform the service adequately remains a topic for further research. However, one factor that does need to be considered is that of price, both in terms of what the customer is willing to pay, and what is an appropriate financial return for a medical practitioner's time and skills.

For a diving medical examination SPUMS members currently charge an average of $60, or twice the price of a GP's regular consultation. Given that the cost of a diving medical cannot be claimed under Medicare, commercial dive operators consider $40 to be a more reasonable price to pay for the service. The difference between the two groups is not large, but for operators in price sensitive markets (like backpackers) this difference may explain the current practice of shopping around for dive medicals.

Commercial operators are probably unreasonable in suggesting that a doctor should perform a diving medical examination for as little as $20, since the medical detailed by Rooney takes at least 30 minutes to perform.[10] The recommended price for a life insurance medical is $77, which, as it takes much the same time, has been used in the past to determine the fee for a diving medical. On the other hand, there are some vast differences in current fees, with some doctors charging 5 times the price of their colleagues for supposedly the same service. No price fixing was evident!

To place the price of a medical examination in perspective, the average cost of an open water course in Australia is $300.[11] A two tank boat dive is around $85, while one day's hire for a full set of dive equipment is around $50. In the context of these charges cost will remain a distracting factor in the important debate about diving medicals.

References

1 Edmonds C. MMM, the Mickey Mouse medical. *SPUMS J* 1986; 16 (10): 3-4.

2 Department of Industrial Affairs. *Workplace Health and Safety Regulations*. Brisbane: Queensland Government Printer, 1989.

3 Division of Workplace Health and Safety. *Code of Practice for Recreational Diving at a Workplace*. Brisbane: Queensland Government Printer, 1992.

4 *Australian Standard 4005.1-1992. Training and Certification of Recreational Divers. Part 1: Minimum entry-level SCUBA diving*. North Sydney: Standards Association of Australia, 1992.

5 Wilkins PS. AMA position on diving medicals. *SPUMS J* 1993; 23 (1): 22-24.

6 Wilks J. Profiles of the travelling diver. In: Wilks J, Knight J, Lippmann J. eds. *Scuba safety in Australia*. Melbourne: JL Publications, 1993, 64-75

7 Wilks J. Price structure and marketing of scuba refresher courses. *Sources* 1992; 4 (6): 46-48

8 *SPUMS members who perform diving medicals in Australia*. Published as a supplement to *SPUMS J* 1991; 21 (3):

9 *The SPUMS Diving Medical*. Published as a supplement to *SPUMS J* 1992; 22 (2):

10 Rooney M. Medical preparation for diving the Great Barrier Reef. *SPUMS J* 1993; 23 (1): 27-29

11 Esguerra R, Ashbolt L. and Callenbach P. *Report on a Study of the Australian Diving Industry*. Sydney: Dive Industry and Travel Association of Australia, 1989

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SPUMS NOTICES

MINUTES OF EXECUTIVE COMMITTEE MEETING TELECONFERENCE

held on 22.8.93 at 1800 Eastern Standard Time

Present

Drs D Gorman (President), C Meehan (Secretary), S Paton (Treasurer), J Knight (Editor), D Davies (Education Officer), C Acott and G Williams.

Apologies

Drs A Slark and J Williamson

1 Minutes of the previous meeting

These were accepted as a true record.

2 Business arising from the minutes.

2.1 Workshop at the 1995 meeting and guest speakers. The theme for the 1995 conference is to be Fitness For Diving. It was decided that this could be a good topic for a workshop and that the whoIe conference could follow the format of a workshop.

Suggestions for discussion topics were asthma (possibly including discussion on attitudes to diving and asthma in different countries), ENT problems and some suggestions from the questionnaire (diving and the disabled, dive fitness re-accreditation, and diabetes).

The following speakers were suggested, Sandra Anderson, Andy Veale and David Dennison (respiratory physiology), Joe Farmer (ENT); Nick McIver, David Elliott, Phil Bryson and Fred Bove (fitness to dive).

Choices to be made at the next meeting

a The whole conference in the form of a workshop on Fitness to Dive.

b Theme: Fitness to Dive and Workshop: Asthma:

c Theme ENT Problems and Workshop: Fitness to Dive

2.2 Theme and workshop topics for future meetings

To be discussed at a later meeting

2.3 Rabaul ASM

2.3.1 Computer manufacturers are very interested in attending the conference.

2.3.2 Diving depth limit set at 39 m (130 feet).

2.3.3 A lot of interest in the conference has been expressed from the USA. They should get their notification of derails about two weeks later than Australia.

2.3.4 People have inquired about doing EAR and CPR in the water. It is hoped to make this part of the conference as the theme is The Management of Diving Accidents.

2.3.5 Expenses: Registration fee is based on 100 delegates. It includes; $35 transfer fee for the Gala Dinner, which will be held away from the hotels; travel bags at $10 (it was suggested that hats may be better or a choice given); $10 for sending out tickets by courier; printing was quoted as $2,000 over all (Dr Knight considered that if the Journal produced the brochure this could be done for less); $3,000 for telephone calls (not specified); $500 for oxygen (this could be funded by the savings from printing and travel bags)

2.3.6 Allway's accountants will be sending all the committee members a statement outlining the running costs of the SPUMS account.

2.3.7 Sponsorship: Pfizer may supply doxycicline, and other possible cash sponsorship being organised by Dr Williams.

2.3.8 It was suggested that the sponsorship money and the money saved on printing and travel bags should go to reduce the registration fee. Also it could be spent on subsidising the drinks at the gala dinner.

2.3.9 Unanimously decided that Russel Kitt is not acceptable as a dive guide. Dr Acott to inform Geoff Skinner and to recommend Paul Lunn.

2.3.10 People are to have a daily choice of boats. Some people may have to be told that specific dives are beyond their capabilities.

3 Treasurer's report

Approximate total of $55,000 in the two accounts.

4 Correspondence

4.1 Letters about the Palau conference. Dr Meehan to answer those which require an answer.

4.2. Letter from Dr Bob Thomas: Dr Knight to respond by publishing correspondence with the AMA and his article in *Australian Medicine*.

4.3 Dr R Tomlin's letter about the minimum age recommended for diver training and SPUMS policy. A similar letter was received from Mr Marfleet, Queensland Health and Safety diving inspector. Dr Meehan to reply quoting SPUMS policy (done 20/9/93)

5 Other business

5.1 The next few venues for the ASM require malaria prophylaxis. This raises difficulties for pregnant women and children. It was decided to go to a non-malarial area in 1996, probably Fiji.

5.2 It was reiterated that all papers at the ASM are for publication in the Journal and must be presented to the convener before presentation.

5.3 DCS and CAGE are now grouped as Decompression Illness, after treatment only those with evidence of pulmonary barotrauma are not fit to dive.

5.4 The price of a diving medical, which includes audiometry, has, in the past, been aligned with that of an insurance medical and report. The current price is $77.00. Dr Knight will insert this in the next editorial.

S0UTH PACIFIC UNDERWATER MEDICINE SOCIETY DIPLOMA OF DIVING AND HYPERBARIC MEDICINE.

Requirements for candidates

In order for the Diploma of Diving and Hyperbaric Medicine to be awarded by the Society, the candidate must comply with the following conditions:

1 The candidate must be a financial member of the Society.

2 The candidate must supply documentary evidence of satisfactory completion of examined courses in both Basic and Advanced Hyperbaric and Diving Medicine at an institution approved by the Board of Censors of the Society.

3 The candidate must have completed at least six months full time, or equivalent part time, training in an approved Hyperbaric Medicine Unit.

4 All candidates will be required to advise the Board of Censors of their intended candidacy and to discuss the proposed subject matter of their thesis.

5 Having received prior approval of the subject matter by the Board of Censors, the candidate must submit a thesis, treatise or paper, in a form suitable for publication, for consideration by the Board of Censors.

Candidates are advised that preference will be given to papers reporting original basic or clinical research work. All clinical research material must be accompanied by documentary evidence of approval by an appropriate Ethics Committee.

Case reports may be acceptable provided they are thoroughly documented, the subject is extensively researched and is then discussed in depth. Reports of a single case will be deemed insufficient.

Review articles may be acceptable only if the review is of the world literature, it is thoroughly analysed and discussed and the subject matter has not received a similar review in recent times.

6 All successful thesis material becomes the property of the Society to be published as it deems fit.

7 The Board of Censors reserves the right to modify any of these requirements from time to time.

CONSTITUTIONAL AMENDMENT.

The following motion was passed by the 1993 Annual General Meeting *That the words "30th June" appearing in rule 2 (a) be changed to "31st December"*.

In the last issue (page 148) members who disagreed with the motion were requested to lodge a written objection with the Secretary beforeNovember 1st. As no member had lodged an objection by that date the Rules of the Society have now been amended.

Cathy Meehan
Secretary of SPUMS

SPUMS ANNUAL SCIENTIFIC MEETING 1994

will be held at
Rabaul, Papua New Guinea
MAY 14th to 22 1994

A brochure was included with the last issue.

The theme of the meeting will be "The causes and management of diving accidents". It will address such issues as diver retrieval from the water, the in-water management of the unconscious diver and whether EAR and CPR should be attempted in the water. There will also be a workshop on dive computers.

If any member or associate wishes to present papers on these topics please contact the Convener, Dr Chris Acott, as soon as possible at
1 Landscape Crescent, Highbury, South Australia 5089.

For further information contact Allways Travel
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LETTERS TO THE EDITOR

DIVING SAFETY RESEARCH

Centre for Public Health Research
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Dear Editor

The massive industry controversy and negative media attention which focused on diving regulations in Queensland during 1991 seems to have faded. Most of the original regulations have been repealed in favour of an industry Code of Practice.[1] However, some of the original issues identified by practising scuba instructors appear to have been largely ignored. For example, instructors expressed concern that there was no research used to guide the decisions of the government committee.[2] Despite repeated requests by the recreational dive industry to furnish the accident statistics that supposedly showed an alarming increase in scuba injuries leading to the original legislation, none have ever been produced. Indeed, it is possible that they do not exist in documented form.

Independent studies have since indicated that scuba diving in Queensland is a relatively safe activity,[3,4] especially when compared with recreational sports in the United States.[5] While acknowledging that the figures for Queensland are very conservative, and incomplete in their coverage, the safety rate is still excellent.

Even though independent studies are now available, the Queensland government has again been badly advised in the area of dive research. A current government-funded study is not gaining operator support or co-operation. This is an unfortunate waste of $52,000 over one year for a study of diving accidents.

Many SPUMS members, and selected members of the recreational dive industry, have been invited to participate in a dive research seminar planned for Cairns in October, 1994. This is to be the venue for the release of data from the government-sponsored study. Unfortunately, considering the current lack of industry support in providing accurate figures for the study, the results may be less than complete.

This is not to suggest that this type of data, professionally collected by people who have the confidence of dive industry members, is not a critical component in safety planning and management. Project Stickybeak, and the personal integrity of Dr Douglas Walker, is an example of what can be achieved. More recently, Dr Chris Acott and his colleagues have made some very positive proposals in their Diver Incident Monitoring Study (DIMS).[6,7]

Diving appears to be a safe sport in Queensland, but systematic research by industry-supported groups needs to continue. Too often money, time, and valuable resources have been wasted by commissioning outsiders to obtain a picture of diving.[8] These consultants may be well-meaning, but as Williamson recently observed, research funds are scarce so they must be used effectively.[9] Inaccurate data leaves everyone disappointed, and may lead to many misunderstandings, such as those which have thankfully passed with the original Queensland diving regulations.

Dr Jeff Wilks

References

1 Division of Workplace Health and Safety. *Code of Practice for Recreational Diving at a Workplace.* Brisbane: Queensland Government Printer, 1992
2 Wilks J, Beecham V. Consumer perceptions of workplace health and safety legislation. *J Occup Health Safety - Aust NZ* 1993; 9: 229-236
3 Wilks J. Calculating diver numbers: critical information for scuba safety and marketing programs. *SPUMS Journal* 1993, 23 (1):11-14
4 Wilks J. Scuba safety in Queensland. *SPUMS Journal* 1993, 23 (3): 139-141
5 Divers Alert Network. *DEMA draft for 1990 accidents and fatalities.* Durham, North Carolina: Duke University Medical Center, 1991
6 Acott C, Sutherland A, Williamson J. Anonymous reporting of diving incidents: a pilot study. *SPUMS Journal* 1989; 19: 18-22
7 Acott C. Scuba diving incident reporting. In: Wilks J, Knight J, Lippmann J. eds. *Scuba safety in Australia.* Melbourne: JL Publications, 1993: 76-84
8 Esguerra R, Ashbolt L, Callenbach P. *Report on a study of the Australian diving industry.* Lindfield, New South Wales: Diving Industry and Travel Association of Australia, 1989
9 Williamson J. Shrinking diving research dollars. *SPUMS Journal* 1993, 23 (3): 137-139

BOOK REVIEW

PROCEEDINGS OF THE 10th INTERNATIONAL CONGRESS ON HYPERBARIC MEDICINE

Editor D J Bakker
Best Publishing Company, PO Box 30100. Flagstaff, Arizona 86003-010100, U.S.A.
Price from the publishers $US 35.00. Surface mail to Australia $US 6.50

The Tenth International Congress on Hyperbaric Medicine was held from August 11th-18th 1990 in Amsterdam in the Netherlands. This was a joint meeting with the European Undersea Medical Society and the Undersea and Hyperbaric Medical Society. The International Congress for Hyperbaric Medicine is a group of hyperbaric physicians with a particular involvement in clinical medicine, and was rounded by Dr Boerema of Amsterdam. It holds a scientific meeting every three years, and the twelfth was recently held in Fuzhau, Republic of China, in September 1993. This makes it probably the oldest hyperbaric medicine society.

The book contains 44 papers presented at that meeting. It starts with the address of the President, D J Bakker, who opened the joint congress. He described how in 1963 Professor Boerema invited 104 people from all over the world to Amsterdam to take part in what he called an international congress on the clinical application of hyperbaric medicine.

The book covers the usual range of papers presented at such meetings. It is well printed and well laid out, and tables and figures are clearly presented. Bibliographies are clear and pertinent, and the book is of a size suitable for easy carrying.

An index would have been of value, as the only clue to what is in the papers is their titles which are listed in a contents section at the beginning.

Many of the papers reward the seeker after information with excellent state of the art treatises on aspects of hyperbaric medicine.

Less than a dozen of the papers are basic science, most of the rest are reports and investigations into the use of hyperbaric oxygen in clinical medicine. Two papers on the use of hyperbaric oxygen therapy in diabetics, by Oriani et al. and by Mathieu et al. are particularly well presented.

This book should be on the shelves of all hyperbaric medicine units as a reference. It is of value to all who attended the Amsterdam meeting, and to others with an interest in clinical hyperbaric medicine who missed it. The International Congress is to be commended on publishing the proceedings. This involves a considerable amount of effort, as trying to obtain manuscripts from speakers after the event is a fairly hopeless task. The abstracts are never as good as the full published papers

Harry Oxer
Director, Hyperbaric Medicine Unit,
Fremantle Hospital, Western Australia

SPUMS WORKSHOP ON EMERGENCY ASCENT TRAINING

This inaugural policy forming workshop is presented here slightly differently from how it was experienced by the participants. First three papers from past SPUMS Journals, dating back to 1978, are presented. They have been resurrected because they deal with the same problem as the Workshop, how to get divers, who have run out of air, safely back to the surface. Then there are the contributions of people who could not attend the workshop. These are followed by the presented papers, in the order that they were given and the Co-Chairmen's report on the Workshop and finally the SPUMS position on Emergency Ascent Training.

A NEW APPROACH TO OUT-OF-AIR ASCENTS

Paper for discussion at the1977 UMS Workshop on Emergency Ascent December 1977

G.D Harper

Reprinted, with minor changes (metric depths), from *SPUMS J* 1978; 8 (July-Dec): 14-17

The various instructor organisations in the world have been plagued for some time 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' organisations 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 recognise that once panic occurs our ability to influence the out-come 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 to 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 does not necessarily involve practising it. The Federal Aviation Authority suspended the practising 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 to disasters. Professional instructor organisations have prepared various statements on ascent training culminating in the National Scuba Training Council (NSTC) ascent agreement.

In this agreement which is quoted in the abstracts, the first two options to be presented to students are :

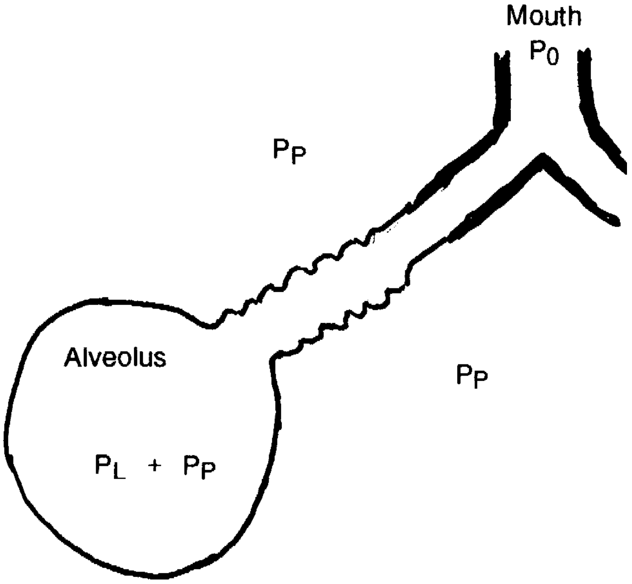
1 The use of octopus regulator
2 Buddy breathing

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 a 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 from earliest times that a closed glottis is a potential hazard. Passively holding the glottis open is a difficult feat; reflexes tend to close it at all times when respiratory activity does not require it to be open. Recently Dr A.C.Bryan while conducting a study at Toronto Sick Children's Hospital, using physiologist physicians as subjects, found only four of nine could perform this act. To avoid this problem Stenke advocated having the subject's head 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 Bhenke 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

FIGURE 1)

PRESSURE RELATIONSHIPS WITH THE AIRWAYS OPEN.

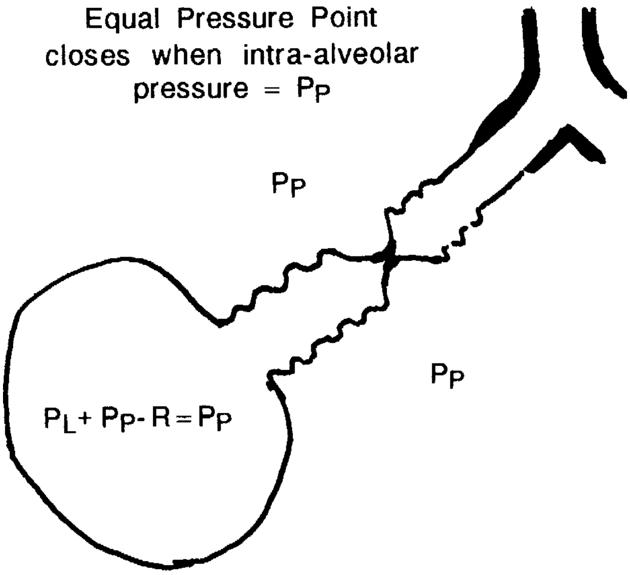


P_P = Pleural pressure (large)
P_L = Elastic recoil of lung (small)

As flow begins resistance to flow causes pressure to drop. Then eventually this drop equals P_L.

FIGURE 2

AIRWAY CLOSURE AT THE EQUAL PRESSURE POINT.



Once closure occurs, how does it reopen ? Surface tension holds it closed if the lung volume decreases. There is little elastic recoil and P_L is very small.

the ascent, to the potential hazards. We know from work by a large group of researchers, including Macklin et al. and Fry 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 Dahlback and Lundren. If we examine now a sequence of alternatives for a hypothetical lung perhaps the difficulties will be more readily appreciated. As our principle concern is with sports divers, a suitable depth from which to start their hypothetical ascents would be 15 m (50 ft) with the diver starting at or near functional residual capacity (FRC) as the diver most frequently becomes aware of his plight when he attempts to breathe in after normal expiration.

At this point the state of affairs in the lung can be represented as shown in Figures 1 and 2. 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 residual volume (RV) and then hold this breath to the surface, or "blow and go". As the glottis is closed during this manoeuvre, if the ratio of RV to total lung volume (TLV) 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 RV/TLV 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 towards the surface. The intrapleural pressure starts off negative. As the lung expands, it becomes less negative due to the attempt to rebound to functional reserve volume (FRV) which in water is lower than FRC in air, but as the gas in the lungs expands it too becomes positive. The forces which produced the airway closure are no longer operative. The lack of interdependent forces has been restored by parenchymal expansion. The dynamic flow situations leading to the locating of the equal pressure point, of Mead, Macklin and others, within the collapsible segment of the airway are not longer present, as the 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 18 m (60 ft) 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 from 15 m (50 ft) to the surface, it may rupture. Note that the first alveolar units to close are those with the lowest elastance or highest compliances. Continued 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 interruption 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 out-flow resistance is minimal. The gas is free to behave in accordance with the dictates of Boyle's law, unless the ascent rate exceeds the maximum rate seen with the Stenke 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 sports diver.

Sports divers rates of ascent even when buoyant would rarely approach 60 m (200 feet) per minute 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 emphasise 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 18 m (60 feet) to the surface and 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 out students to expect to run out of air on every dive. We teach them to do the usual safety checks, and to use underwater gauges and octopus regulator. We also teach them not to argue with their gear under water. 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 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. Next, in 3 m (10 ft) 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 emphasise 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 7.5 m (25 ft) and air off ascents gradually increasing from 3-9 m (10-30 ft) on a tethered line, one on one, with the instructor's hand on the air valve.

For special candidates who dive with unisuits such as Canadian Government Arctic divers, we also do progressively staged blow ups from depths to 9 m (30 ft) 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 lung studies give pressures of 4.5 cmsH_2O (Burger and Macklin) to re-expand 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 LaPlace 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 organisations can standardise 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 from alveolar rupture due to trapping.

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

Dr D.G.Harpur is Medical Director, Tobermory Hyperbaric Facility, Tobermory, Ontario, Canada.

FIRST AID PRIORITIES FOR DIVERS THE TOBERMORY VIEWPOINT

G. Harpur

Reprinted, with minor changes (metric depths and weights), from *SPUMS J* 1982; 12 (Oct-Dec.) 32-38

Due to the large number of divers attracted to the Tobermory area by the clear waters and abundant marine artifacts, we are provided with many opportunities to examine those events surrounding diving accidents which influence their outcome. In the past year approximately 30,000 dives were carried out, principally between the 24th May and the Thanksgiving weekend in October, by some 7,500 divers of whom 30% were student divers on their initial open water experience. Since 1974, there have been 36 accidents resulting in major injury to divers as well as countless minor incidents with less serious sequelae. In this paper I intend to present a review of the more serious incidents and accidents with particular attention to those factors which contributed to the serious or fatal outcome.

Our figures indicate that on any given dive in the last two years, the diver's chance of being injured was 0.04% and of being killed was 0.003%. These figures do show a higher incidence than is reported elsewhere, e.g. the Rhode Island surveys, and may reflect the effects of cold water and the high proportion of novice divers. Training accidents have been rare, with only 1 fatality and 2 serious incidents occurring in the past 7 years.

TABLE 1

FACTORS RESPONSIBLE FOR INCIDENTS WHERE A DIVER FAILED TO SURFACE OR SURFACED WITH ASSISTANCE

Diver fitness

Training

- None or taught by a friend
- Diving alone
- Improper response to :-
  - freeze-up
  - emergency ascent
  - buoyancy control
  - shallow water blackout

Psychological State

- Unfit
- Temporary conditions
- Pre-existing long term conditions

Medical Conditions

- Temporary
- Pre-existing long term

Equipment

- Inadequate
- Malfunction

Rescue

- Poorly organised or not plan
- Improper technique

There have been 16 deaths in the period 1974 to 1981, out of a total of 36 serious accidents. Of these deaths, 11 died before reaching the surface, 3 died after reaching the surface but before reaching the recompression facility and 2 died after completing an initial treatment table. The remaining 20 divers all survived and were entirely intact, so far as could be clinically determined, after one or more treatment runs. There were no survivors who sustained any long term injuries as a result of their accidents. This type of sharp division is probably unusual and can be most likely explained by the unique character of our situation in Tobermory. Most of the diving takes place within the confines of Fathom Five Provincial Park and this area is controlled by both Ontario Provincial Police (OPP) and Park staff routinely, so a very rapid response to any accident is possible. The average time from the victim arriving at the surface until being placed back under pressure, when indicated, is between 30 and 40 minutes. This organisation also permits a very detailed investigation of each incident and accident to be carried out at the same time as the victim is being treated. Park staff and OPP dive team member conduct interviews with other members of the diving group. In more serious cases, exhaustive studies are conducted on the equipment and air supply, with the assistance and such technical support as Defence and Civilian Institute of Environmental Medicine (DCIEM) and the Centre of Forensic Science in Toronto.

If we consider first the group of divers who failed to make the surface on their own, we can divide them into subgroups according to the various factors which accounted for this failure in each case. In some of the accidents, more than one of the factors listed in table 1 may have been present. The following brief case histories serve to illustrate these points.

Diver fitness

TRAINING

Fortunately we have not encountered many cases of diving without formal instruction which have resulted in problems in Tobermory, although these are common elsewhere. The one example we have illustrates a combination of informal instruction, diving alone and inadequate equipment.

DIVING ALONE

P.H., a 26 year old male, who had just completed his PhD. in Maths and Physics, and who was a self taught skin diver, was free diving to 15-18 m (50-60 ft) depth in an area off the shore of Georgian Bay which had a flat bottom, sloping gradually to depth in excess of 30 m (100 ft). He had no buddy, but there were several groups of scuba divers in the same general area. His friends on shore wandered away for a period, as they were accustomed to his being out for periods up to one and a half to two hours. He was not on the shore or visible in the water when they returned. After a period of confusion and trips to his car 1 mile away, the alarm was raised. It was now dusk. His body was located the next morning by OPP divers in 21 m (70 ft) of water. It was on the bottom with 7.3 kg (16 lb) of lead in place, a full wet suit, mask and flippers and no buoyancy device. Another weight belt, visible from the surface, with 8 kg (18 lb) of lead on it, lay nearby. Autopsy determined the cause of death to be drowning. His lack of adequate training undoubtedly left this diver unaware of how rapidly shallow water blackout occurs, and his lack of a vest reduced his options.

We have not been able to document a single case in which equipment malfunction directly caused a diver's death or injury. It has always been the diver's response to the problem which results in the pathology. Recognition of the malfunction and effective management of it are part of good diver training. The following cases illustrate areas where the job is still being inadequately done.

INAPPROPRIATE RESPONSES: FREEZE-UP

Regulator freeze-up is a common event in cold water, which is to say in all water deeper than the thermocline in Canadian lakes at any time of the year. Proper training should reduce unnecessary use of the purge button, anxious panting and heavy exertion which encourage this problem. All students should be aware of the problem, exposed to it and taught how to recognize it and how to respond appropriately. That is by breathing off the free flowing regulator to the surface. Failure to do this has been the initiating event in several incidents, two of which resulted in fatality.

In the first of these, the individual who died was an innocent bystander.

J.M. was an 18 year old male diver who, after qualifying the day before, was persuaded to participate in a badly conceived dive to 21 m (70 ft) off Flower Pot Island. Four divers took part. Two had previous experience to 21 m (70 ft) in warm water, and formed one buddy pair. J.M.'s buddy had one previous dive to 30 m (100 ft) in cold water. None of the divers were familiar with the site. No shot line was dropped to confirm depth, despite the fact that depths in excess of 90 m (300 ft) are encountered in this area.

Difficulty with buoyancy control was encountered by all the divers during the descent as they had all weighted to neutral trim at the surface and failed to anticipate the effects of wet suit compression. This resulted in a rapid descent and the divers found themselves very unexpectedly at 27 m (90 ft), just 6 m (20 ft) off the bottom in clear 4°C water.

At this point, one of the pair of warm water divers encountered a free flow probably secondary to anxiety and overbreathing. He abandoned his regulator and attempted buddy breathing but was unsuccessful due to numb lips. His buddy now abandoned him, ascending rapidly. J.M.'s partner, the most experienced diver, took over. The three remaining divers were on the bottom at 33 m (110 ft) at this point. The CO_2 cartridge, a 25 g size on the victim's vest had been pulled with no apparent effect. (See the later section on vests). The attempts to force buddy breathe the victim were moderately successful. This pair of divers swam up after dropping the victim's belt. J.M. was following in no apparent difficulty. At 15 m (50 ft) the rescuer ran out of air, pulled his reserve and continued up with the victim. J.M. was still in attendance. At 9 m (30 ft) the rescuer completely ran out of air, dropped his weight belt, blew his vest and released the victim who was now positively buoyant. Both divers arrived on the surface where the other diver was waiting. The victim was in fair shape although he underwent prophylactic recompression for possible cerebral embolism at Toronto General Hospital later.

J.M. never arrived at the surface. Lack of planning led to the confusion and delay in the rescue attempts. The body was recovered 4 hours later by OPP divers on the bottom, in full gear with his vest and CO_2 cartridge intact (i.e. not activated). Autopsy showed death was due to massive air embolism. The degree of mask squeeze present suggested that J.M. made a breath hold lunge for the surface when the other divers took off from 9 m (30 ft). His tank contained air and there was no evidence of equipment malfunction.

Although J.M. did not encounter free flow, the failure of the initial victim to deal properly with this event initiated the sequence which led to his death.

The second example illustrates a much more direct effect.

S.G., also an 18 year old male, was making a dive on the Arabia, which lies in 33 m (110 ft) of water. He too was a low time diver, but did have several hours of post certification diving at depths of up to 12 m (40 ft) in cold water. The temperature at 33 m(110 ft)was 4°C as usual and the visibility 12-15 m (40-50 ft) in low light. He encountered a free flow at 30 m (100 ft) early in the dive, and abandoned his regulator. His buddy commenced buddy breathing with him, but S.G. refused to return the regulator. The buddy dropped his belt, activated his CO_2 vest and swam up, dragging the victim, he thought, by the regulator, When he arrived on the surface, S.G. was not with him. The body was recovered several hours later in full gear and with an intact CO_2 cartridge. Autopsy showed death had been due to massive air embolism to all major vessels, with damage to both lungs. Panic induced by an inappropriate response and the surprise of an unfamiliar problem had claimed another victim.

There were also many minor incidents which avoided a similar conclusion only by chance. One, which was somewhat amusing, involved a fellow and his girl in 9 m (30 ft)of water. The girl encountered a free flow and abandoned her regulator. He being chivalrous, gave her his. She refused to relinquish it. As in the last case, he bounced to the surface, dragging her with him, but in this case she was unharmed. The abrupt development of a romance-shattering insight was the only damage done.

The major problem in all these cases arose because of an inappropriate response i.e. abandoning the regulator. This indicates a flaw in basic training. Good free flow simulation is possible. OUC have recently published a modification to a standard scuba set, devised at Tobermory, which will permit any student to be exposed to this problem and its management, in the safety of the pool.

INAPPROPRIATE RESPONSES :
EMERGENCY ASCENT

Even with the best of training and planning and equipment, if one dives long enough one will encounter an out of air situation, more frequently if one neglects any of the foregoing.

The inadequacy of the responses currently being taught for use in this situation, are illustrated by the next series of cases.

J.K. was another 26 year old male diver. The frequency of this age and sex combination begins to look like an ill omen. He was performing an emergency ascent from 9 m (30 ft) in open water as part of his graduation exercises. The drill to be followed was :

1. remove the mouthpiece
2. undo the weight belt and pass it your buddy
3. swim up, humming constantly, with the instructor and flare at about 1.5-3 m (5-10 ft).

J.K. commenced his drill but fouled up at 2, when he undid his tank strap. He replaced his regulator, refastened his strap and after a brief rest, started again. He completed the exercise correctly and was observed to be exhaling, presumably by humming, throughout the ascent, by his instructor. At the surface he was immediately asked how he felt. He replied, “I feel fine”, just before passing out and convulsing. CPR was effectively applied and he was evacuated to the beach and subsequently to the hyperbaric chamber, in approximately 25 minutes, where an immediate table 6A with extensions was commenced. He recovered spontaneous respiration and circulation after drainage of bilateral pneumothoraces, and remained stable despite repeated recompression. He died 4 days later of brain infarction. Examination of his equipment and gas analysis revealed no problems.

J.K. had approximately 10 litre lungs. If we assumed that he near filled his chest before his attempted ascent, the outcome is easy to explain. Humming does not permit a lot of air to escape. The amount necessary to produce a good hum can be as little as 50 ml/second. A hard hummer can get rid of 500 ml to 1 litre/second, but averages are probably around 250 ml/second. From 9 m (30 ft) to the surface, J.K. had to clear 9 to 10 litres if he was to avoid disaster and his ascent time was 6 to 7 seconds. Humming obviously could not do the job. Unfortunately the lungs provide little warning of the impending disaster as evidenced by his “fine”. The tragic part is that his unimpeded airway had the capacity to handle flows in excess of 10 litre/second, more than 6 to 7 times his requirement. The obvious solution is to teach an ascent technique which keeps the airway open. (See continuous breathing cycle ascent below).

Probably the commonest emergency ascent technique taught is the continuously exhaling pattern. This mode of ascent was definitely used in 8 of our embolism cases who survived, in one of the fatal cases for certain, and it is highly probable it was the technique used in 4 others. This constitutes about 60% of the fatalities and about 75% of the casualties, due to ascent technique.

The case of diver T.R., a 42 year old male, assistant diving instructor illustrates this very well.

T.R. had completed a well organised dive with his club on the Arabia and was making the ascent from 33 m (110 ft) when he decided that since he was ascending a little faster than the normal 18 m (60 ft) a minute, he should probably do what he taught his students to do during fast or emergency ascents i.e. exhale continuously.

This was the last thing he could recall until he came to in the hyperbaric chamber some hours later. He had arrived at the surface unconscious and not breathing, brought up by his own vest due solely to vest expansion. He had some frothy red sputum coming from his nose. His group followed their emergency training and commenced artificial respiration (EAR) with the victim on a 20° head low slant and transported him to the chamber. On arrival there he was breathing spontaneously, coughing up some bloody sputum. He was still very obtunded, responding only to deep pain. Rapid recompression on a table 6A resulted in dramatic recovery within 15 minutes. He was confused for the first one and a half hours after full recovery of consciousness. He kept asking how he could possibly have embolised, as he was so positive about his decision to exhale. We reassured him that although many would doubt him, we did not and explained the mechanism of small airway closure to him and the hazards of exhaling ascents. The sad part is that this diver had adequate air supply and stopped breathing only because he was misinformed.

The degree of embolism sustained in this case was obviously slight and this is typical of the injury which results from low volume air embolism. The embolism does not usually kill directly, but does alter consciousness and lead to drowning. These cases are often missed at post mortem as not many pathologists are well versed in the mechanics of diving injuries. This problem, like that created by the humming ascent, is avoided by the continuous breathing cycle ascent protocol.

INAPPROPRIATE RESPONSES : BUOYANCY CONTROL

In many of the cases where the diver died, the cause of death was drowning and the embolism or hypoxia or fatigue which led to this outcome were not in themselves serious. In these instances a failure to get to the surface or a failure to remain there, was the critical factor in determining the outcome. Many critically injured divers survived because they reached the surface. All of those who remained on the bottom or returned to it, died.

This underscores the importance of the diver making certain that he will continue to ascend even if he loses consciousness. None of the divers recovered from the bottom had dropped their weight belt, and none had deployed the CO_2 cartridge or otherwise fully inflated their vest.

The case of P.H. cited earlier, illustrated the effects of hypoxia in free diving. Many scuba divers fail to appreciate that once they are out of air they too can become critically hypoxic during ascent for the same reasons. Calculations show that a diver who runs out of air and then attempts to swim up with no assistance from vest or from dropping a weight belt runs a significant risk of abrupt loss of consciousness during the ascent if he starts deeper than 15 m (50 ft). In trial runs from 18 m (60 ft) in the chamber at Tobermory, while exercising at a level equivalent to such a swimming ascent, two subjects were unable to complete a simple secondary task all the way up, both becoming confused at depths greater than 1.8-2.1 m (6 to 7 ft). A repeat run from 27 m (90 ft) resulted in one subject getting into difficulty with confusion at 6.3 m (21 ft), the other at 4 m (13 ft). Such confusion under water could result in loss of control and breath holding, with subsequent embolism or aspiration of water and drowning.

A good example of this is the case of L.C. a 27 year old diver on her first night dive in the company of an older more experienced diver. The dive was planned to 9 m (30 ft), but the area of the dive included depths to 27 m (90 ft). Both divers were weighted for a neutral trim at 5-6 m (18-20 ft) with 5.5 and 6.3 kg (12 lb and 14 lb) lead respectively. Some incident led to both women embolising and neither shed her weight belt or inflated her vest, but one surfaced, the other, L.C., was recovered the following day, having drowned following a minimal embolism. I wish I could say the other survived, but she did not for a series of reasons I shall deal with later, but she had a chance, L.C. had none.

Psychological fitness

Many of the incidents, especially those which commence with free flow, indicate that the diver involved was under excessive pressure at the time of the incident.

Most frequently this stress appears to originate in peer pressure. The low time diver attempts a dive which takes him out of his depth and experience in order to be one of the group and prove that he can hack it thus setting the stage for tragedy. As this factor is apparent in many of the cases cited, I will give no specific example.

This same problem, diving while under excessive duress, has led to two cases of spurious decompression sickness. Both of these cases presented as type two decompression sickness but the findings were inconsistent and the complaints variable. Resolution of one case required a sham chamber treatment with descent to 1 m (3 ft) on compressed air resulting in an abrupt and total resolution of all symptoms and signs.

Medical conditions

TEMPORARY

Medical fitness or rather the lack thereof has been a significant factor in both incidents and fatalities. Temporary disability of minor degree has served as the trigger factor in several cases and the commonest example is difficulty with ear clearing. It would appear that we are not doing a very good job of training people in this area. We conducted a survey of novice divers during the summer of 1978 with the results shown in Table 2.

TABLE 2

DAMAGE TO THE EARS OF 186 NOVICE DIVERS

No Barotrauma	79
Minimal	29
Moderate	70
Severe	8
(Bilateral)	(11)

The interesting point about this is that despite the fact the two-thirds had significant trauma to their ears, only one or two recognised this fact.

Most of the problems created by this sort of trouble have been minor. We see a steady stream each summer that we refer to as investors. The people leave home 200 or 300 kilometres away without checking that their ears can clear. They arrive in Tobermory, pay for their charter, rent equipment and get teamed up with a buddy, and still have not checked that their ears clear. Finally at 3-4.5 m (10-15 ft) on the first dive, with all their money and time invested, they discover that their ears are going to be difficult. They proceed to try everything known to God and Man to get those ears to work, frequently winding up in our hands with various types of squeeze or worse.

The effects are not always trivial. There has been one case of a diver, G.P., in whom air embolism resulted from panic at 3-3.6 m (10 to 12 ft) over ear pain. He made a breath hold ascent and became confused with bloody cough and voice changes. Response to therapy was excellent and a modified table 6A resulted in his total recovery.

Most serious problems arising as a result of temporary disability are a result of diving while under the influence of drugs, the commonest being alcohol. The partner in the case L.C. cited earlier, was a 42 year old female, K.C. What event led her to embolise during that night dive was unknown. She came to the surface where she added fresh water drowning to her problems because her face was not supported free of the surface with her weight belt on and the vest was not inflated. She vomited and aspirated during resuscitation attempts. Despite effective CPR and surviving her initial chamber treatment, she eventually died with the following injuries: massive air embolism of the cerebral vessels, aspiration pneumonitis and fresh water drowning. Her blood alcohol was reported as twice the legal limit.

Fatigue, alcohol and decongestants figured in the temporary disability which led to the death of T.R., a 26 year old male diver. T.R. drove up to Tobermory during the night, arriving at 0600 hours having imbibed liberally en route. During his first dive of the day at 1000 hours he experienced difficulty with his ears. So he took a couple of Sudafed tablets. This was his first experience with this particular medication, and for good measure he washed them down with a couple of ounces of rye. Two hours later he made a dive to 12 m (40 ft) for 45 minutes. He made an abrupt swimming ascent for reasons which were never elucidated. At the surface, he was confused and could not stay up, succeeding neither in releasing his weight belt nor in inflating his vest. He subsequently lost contact with his buddy and sank. He was recovered by other divers in a few minutes at a depth of 1.2 m (4 ft). He was unconscious and failed to respond to attempts at resuscitation. The cause of death was drowning secondary to minimal air embolism.

Street drugs probably played a significant role in the death of L.S. This 23 year old diver approached two other divers at 30 m (100 ft) with his regulator out. He took the regulator offered him and took one breath returned it, then refused to take it back. The rescuer had located his octopus and offered the regulator to keep, but it was refused. The victim was now in total panic and holding tightly onto part of the wreck Arabia. The rescuers pried his fingers loose and took him up, squeezing his chest, pounding his gut and doing all the things they had been taught to make him exhale.

Unfortunately an air breathing mammal underwater in severe panic will give you almost anything, his lunch, his blood, but not his air so long as he remains conscious. Thus the diver predictably held his breath and sustained a massive degree of embolism resulting in instant irreversible death. Subsequent investigation showed that hallucinogens and cannabis had both been in use. A more effective job of educating sport divers to the hazards of diving while impaired physically, emotionally or pharmacologically is the only thing that will reduce the frequency of these occurrences.

LONG TERM PRE-EXISTING CONDITIONS

The presence of a long term pre-existing medical condition which should contraindicate diving is becoming alarmingly common. What is most disturbing about this is that many of these divers with a history of epilepsy, or asthma, have reported their illness to the physician who did their screening physicals, required to enter Scuba training by most agencies, and were cleared as completely fit to participate in the sport. The consequences of this are well demonstrated by several incidents. I will cite two.

G.B. was a 42 year old diver with a long history of epilepsy which had been under control for more than 20 years, but which still required that he take Diazepam (Valium) on a regular basis. During a dive to 15 m (50 ft), off Lighthouse Point in the Tobermory harbour area, he lost consciousness during ascent while separated from his buddy. Fortunately he was positively buoyant and continued to the surface. His luck at the surface was good as he popped up under the nose of some well trained people who cleared his airway of vomitus and administered effective CPR, which was required. When he arrived at the Hyperbaric facility 20 minutes later he was still comatose and requiring AR, but now had spontaneous heart action present. After 15 minutes at 40 m (165 ft) he showed no signs of recovery. When placed on a breathing mixture of 50% N_2 and 50% O_2 he responded rapidly. Within 5 minutes he was awake but struggling and confused. He remained confused for 4 hours while an extended table 6A was carried out. He then abruptly recovered totally except for a short period of amnesia surrounding the dive. The difficulty with short term memory persisted for several days. His subsequent course was one of total recovery with no sequelae. He no longer dives.

The second case is that of a 59 year old male, V.K., who had pre-existing arteriosclerotic heart disease with a rhythm disturbance, requiring medication, and chronic obstructive lung disease of moderate degree, also requiring medication. At 33 m (110 ft) on the Arabia this diver became stuporous and confused, but was brought up under control by his smaller female buddy in a truly remarkable display of good diving skills effectively and calmly applied. He was coughing bloody sputum and unconscious at the surface requiring EAR. Recovery was rapid but complicated by aggressive behaviour and confusion adding to the problem of his management. At our unit he presented as a case of definite pulmonary barotrauma with bloody, frothy sputum and of fresh water near-drowning of significant degree superimposed on the original maladies. He was hypoxic and confused to begin with. This had been clearing during evacuation and with O_2 and a head low position continued to do so. He had no pneumothorax. However X-rays confirmed the presence of near-drowning and the pre-existing emphysema. As he was improving he elected not to use the chamber in the face of the serious pre-existing disease. Had he been worse or deteriorating our hand would have been forced. He subsequently made a full recovery. I am sure the possibility of a fatal outcome was not missed by much.

To reduce this sort of problem we have just drafted a short article outlining the hazards of scuba diving and listing the factors to be looked for during medical examination to determine fitness for the sport. This is to be reproduced in the Journal of Family Medicine and the Medifacts tapes system, which should bring it to the attention of a majority of primary care physicians in Canada.

Equipment

REGULATORS

Many of the cases already cited, illustrate equipment shortcomings. Regulator freeze-up can be managed. While it cannot be completely prevented by current single hose designs, many companies have produced products which are more resistant than others. To achieve low breathing resistance, high peak flows are required. Many designs have pursued this goal, neglecting the fact that these higher flow rates imply greater adiabatic cooling and therefore greater risk of freeze-up. Divers should be made aware of those designs which best meet both criteria such as the excellent line by Sherwood which we have found very freeze-up resistant.

CO_2 VEST

In cold water the performance of these vests at depth is pitiful (Table 3). Below 18 m (60 ft) CO_2 vests are wholly inadequate in our 4°C waters, even with the largest of cartridges. A vest can be used as a last resort air supply if fitted with the right mouthpiece and if the skill is practised, but if it is full of CO_2 breathing would of course only hasten your demise. A vest with a power inflator does not ease the problem as the one time you really need that vest is when your air supply has gone.

TABLE 3

CO_2 VEST BUOYANCY

Cartridge size	Lift at 27 m (90 ft) in 5°C water	
38 g	2.3 kg	5 lb
25 g	0.9-1.4 kg	2-3 lb
12 g	0.7 kg	1.5 lb

Two young divers, M.Z. and J.S. died while doing the wreck of the Forest City. These divers were wearing CO_2 vests which at 45 m (150 ft) would provide 0.5 kg (1.25 lb) lift when deployed against net negative buoyancy of approximately 4.5- 5.5 kg (10 to 12 lb). Neither reached the surface nor survived, so the exact role played by this deficiency remains speculative.

The diver T.R. referred to earlier drowned because he failed to inflate his vest on the surface. He was unable to do so because it had a power inflator but he was out of air. It had an oral inflator but he was fighting so hard for breath he could not spare any. It had no CO_2 or alternative last ditch fill system.

The solutions are fairly obvious and simple. An independent filling system for the vest. This should be breathable air if one is diving in cold water deeper than 15 m (50 ft). The training required for safe use of the system should be part of all diver training courses. There is a new inadequacy in equipment which, as far as I am aware, has yet to produce a casualty that I would like to mention in passing.

STABILIZING JACKET

The stabilizer jacket is being widely promoted as the ideal buoyancy device. While it is compact and comfortable in most circumstances, fully inflated many models cause significant restrictions to respiration and a sensation rather like what I have always imagined the grip of an octopus might feel like. These effects could be devastating if experienced for the first time in an emergency situation. Divers should be cautioned in this regard. Details of the restriction to respiration will be included in a study to be published shortly.

MALFUNCTION

Equipment malfunction was an initiating factor in many cases, including J.M., S.G. and L.S. and a complicating factor in others, including R.R. and J.G.

I would like to emphasise that the malfunction per se killed none of these divers. It was their reaction to the malfunction that did.

Rescue

This brings me to the last area of difficulty, the response to the accident by other divers. The most frequent cause of difficulty in relation to technique was with CPR. In three of four cases where divers reached the surface but died before reaching the recompression units, faulty or no CPR was involved. In the case of T.R. loose bridge-work lodged in his throat. The rescuers abandoned CPR on R.R. because the victim vomited. As Resusci-Anne never did that they were totally unprepared. In one case, no CPR was attempted because the victim was cold, blue and had dilated pupils. Most divers could get 2 out of 3 on that test after any dive at Tobermory. In the case of K.C. the initial problems were compounded by faulty CPR, which fractured his ribs and may have lacerated the lungs.

CPR training for divers needs to emphasise that unconscious divers in a head low position almost inevitably vomit, in a passive way and that to save these people you must be prepared to clear the airway, spit out the chunks and keep going. Divers must also be taught that the pupillary signs are totally unreliable when dealing with a potential cerebral air embolism.

Organisation and Planning

The following case illustrates almost every factor I have discussed and many more besides.

J.G. was a 30 year old diver, with low time diving with a group who did not know him or his experience beyond the fact that he possessed a C card. His girl-friend was along as part of the group so the pressure was on as the group decided to dive the Arabia. Dive organisation had been fairly good throughout the weekend, but for some reason which was never clear, it was now let slip. The divers were not in standard buddy teams. On the descent one female diver aborted after crossing the thermocline at 24 m (80 ft) and was left alone on the descending line. J.G. continued down. After completing a part of the distance around the wreck one of the more experienced divers noticed that J.G. was already down to 750 p.s.i and directed him back toward the ascending line. He then turned to signal the rest of the group to follow. The girl left behind was at 21 m (70 ft) and came to the surface with the rest of the group, having encountered no other diver. At the surface, the captain of the charter boat, an interested bystander, pointed out that the group was a diver short and the search for J.G. began. There was no-one who had not already dived. So four of those in the water made immediate repetitive dives, one of them twice, using fresh tanks. Finally 20 minutes later J.G. was brought to the surface, dead. Death was due to massive air embolism of the brain and heart. Subsequent investigation revealed that the diver had encountered a free flow, ascended, embolised and sunk to the bottom where he was found. As a result of the repetitive dives committed, we wound up treating 1 case of type 1 decompression sickness and four cases of missed decompression. I do not believe an additional comment is required.

The dual fatality of J.S. and M.Z. on a dive conducted without a safety diver, reserve air or communication 13 km (8 miles) off shore, illustrated the same deficiencies. The old maxim, plan your dive and dive your plan really says it all.

Lessons for First Aid priorities

In this review of the accidents at Tobermory I have attempted to review those factors which could be altered to improve the situation and prevent the accidents or improve the outcome.

First aid has obviously got to start with training if the figures are to change much. Of 15 deaths, 11 failed to surface which certainly limits one's options in dealing with these accidents. Universal adoption of the continuous breathing cycle ascent protocol below would eliminate most of the air embolism cases. Details of this protocol are available on request.

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

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

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

CPR training is the most critical factor to date in determining the outcome if the diver surfaces.

Good dive organisation ensures rapid response and prevents incidents from becoming complicated.

There is no conclusion to this paper, it is in fact merely a beginning in what we hope will become a broader, ongoing review of Canadian diving accidents and incidents leading to improved First Aid for Divers.

HYPOXIA IN OUT-OF-AIR ASCENTS
A PRELIMINARY REPORT

G.A.D. Harpur and R. Suke

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SPUMS J 1984; 14 (4): 24-28

In December 1977 the Undersea Medical Society (UMS) convened a workshop on Emergency Ascent Training[1] in Bethesda, Maryland, supported by a National Oceanic and Atmospheric Administration (NOAA) grant. At the conclusion of the workshop, it was found that rather than answering many of the questions, the conference had served rather to define those areas requiring further investigation.

It was suggested by one of the participants that critical levels of hypoxia were likely to occur in the course of any emergency ascent arising as a result of an out of air situation and that this hazard might well rank with that of air embolism. Surveys of deaths occurring while scuba diving reveal variable numbers of drownings. The Rhode Island survey[2] shows 70% of scuba deaths due to drowning, our own statistics in Ontario[3] indicate a lower figures of 66%. Detailed examination of these reveals that many drownings are secondary to embolism. Others may have been secondary to this or other difficulty but missed due to improper autopsy technique, or no autopsy, but there remains a number of these deaths which may well be due to hypoxia before the surface is reached. Whatever the cause, failure to reach the surface has been uniformly fatal in our experience (Table 1).

TABLE 1

OUTCOME OF 37 SERIOUS DIVING ACCIDENTS TOBERMORY 1974-1982

	Deaths	Survivors
Failed to surface	12	0
Surfaced	3	22

These cases include cerebral arterial gas embolism (CAGE) and carbon monoxide (CO) poisoning

The majority of the participants were sceptical, but the concept appeared to merit further investigation and this paper is devoted to an initial hypothetical analysis of this problem and a preliminary report of a series of experimental ascents to test the hypothesis.

Problem Analysis

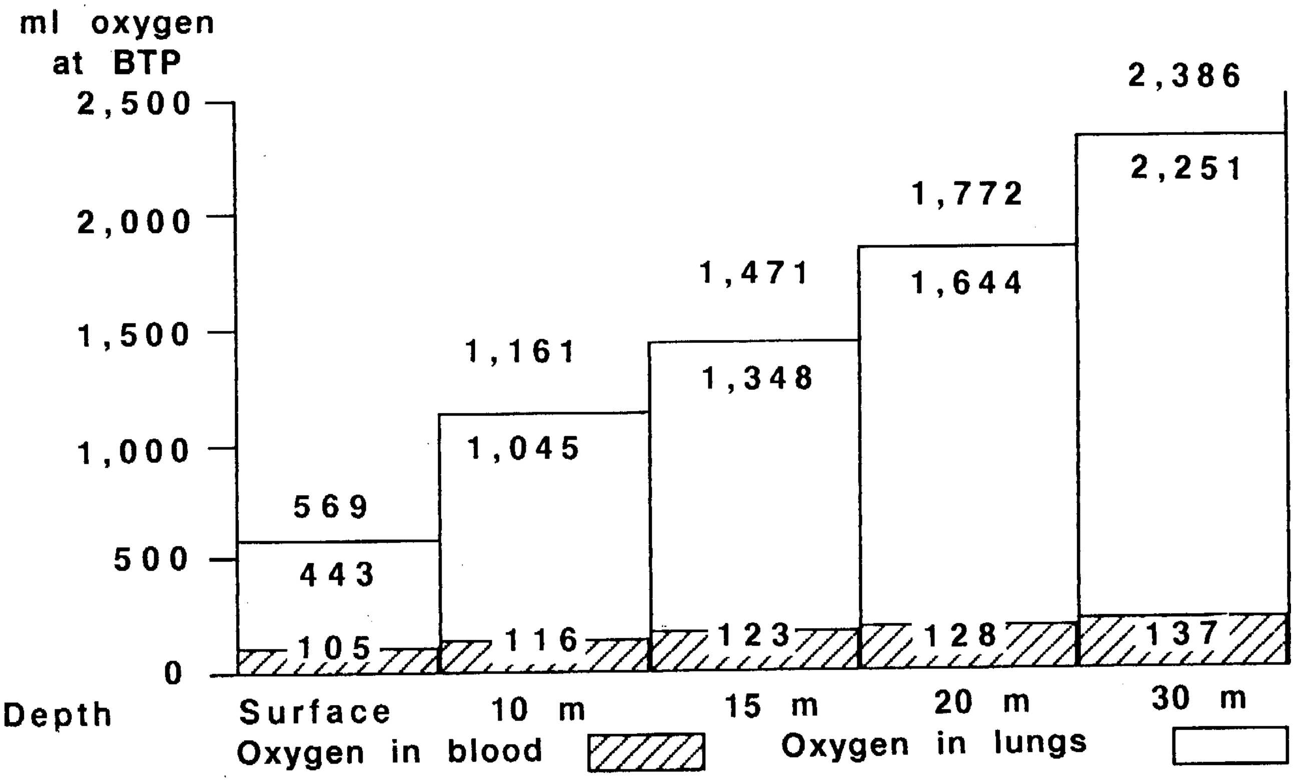
If we analyse the situation which exists when a diver runs out of air, we can derive his available oxygen (O_2), the projected O_2 cost of the ascent, and then predict the course of his PaO_2. Certain conditions must be assumed for this exercise and we have selected the following.

Our diver is an 80 kilo man, reasonably fit with a vital capacity, predicted for 184 cm height and 32 years of age, of 5.7 litres.[4] We have further assumed that he has a haemoglobin (Hb) of 15.0 gm% and a total blood volume of approximately 6 litres represented by 2,042 ml oxygenated blood and the balance mixed venous.[5]

The out of air emergency is assumed to occur while the diver is swimming actively at a level which has pro-

FIGURE 1

OXYGEN AVAILABLE AT VARIOUS DEPTHS.



Oxygen available has been calculated using a starting PaO_2 of 116 mm Hg and assuming lung volume to be FRC (2.9 litres).

duced a steady state and that the lack of air is discovered by the diver, when he attempts to breathe in following a normal expiration. He is assumed to be in standard sport diving dress (wet suit and fins).

The diver is presumed to respond to this emergency within 3 seconds by initiating an ascent and remaining neutrally buoyant throughout. Whatever breathing routine is employed during the ascent, the hypothetical diver unloads sufficient gas to stay at his FRC (2.9 litres).[4] We neglect the decrease in this value which has been shown to occur with head up immersion due to the chest wall pressure gradient. Most authors have shown this to be of the order of 30%.[6]

Figure 1 outlines the oxygen available on the bottom for the depth or pressures indicated.

Work by Lanphier[7] and other authors has shown that the optimum swimming rate for a diver with fins is approximately 27 m (90 ft)/minute, and that at this rate the O_2 consumption equals 1.5 litres/minute.

Using the total O_2 figures from Figure 1, less the amount lost in expired gas as the diver ascends, we can calculate the depth at which the diver's Pa O_2 will cross the critical value of 40 mm Hg which, in most of us, would result in abrupt loss of consciousness during such an ascent (Figure 2 and Table 2). It is at once apparent from this bar graph that the critical situation will always arise close to the surface but that in all cases where the ascent is commenced from depth of more than 13.5 m (45 ft) of sea water, it takes place before the diver can hope to breathe surface air.

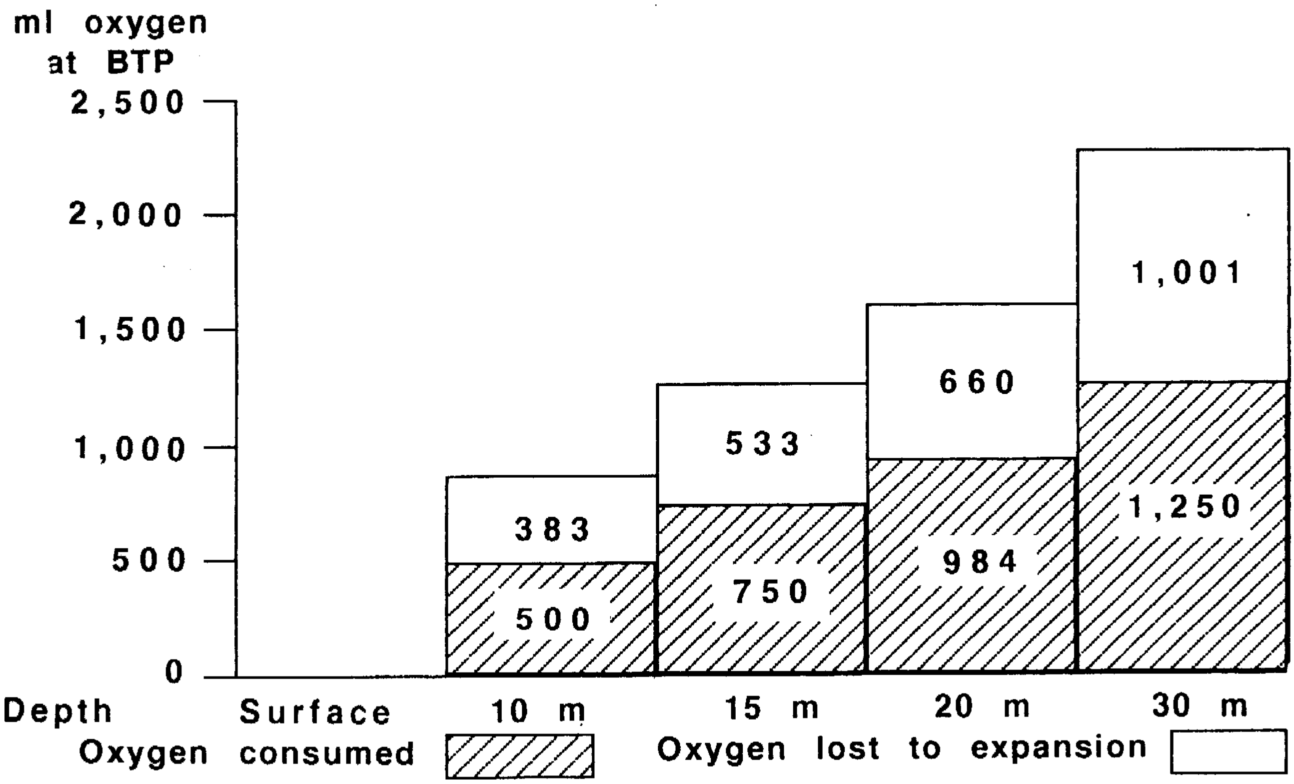
One of the conditions we assumed for this ascent at its outset was neutral buoyancy, so if the hypothetical diver loses consciousness he will not continue to ascend, rather he will lose his regulator and take in water, thereby simultaneously drowning and becoming negatively buoyant making effective rescue and survival improbable.

Method

To test this theoretical case, two divers were subjected to repeated ascents in circumstances as close to those specified as it was possible to approach with reasonable safety.

FIGURE 2

OXYGEN COST OF ASCENT



Starting depths are given in metres of sea water. The lung volume is assumed to be FRC (2.9 litres) at the start of the ascent and ascent rate 30 m (99 ft) per minute.

TABLE 2

DEPTH OF EXHAUSTION OF OXYGEN

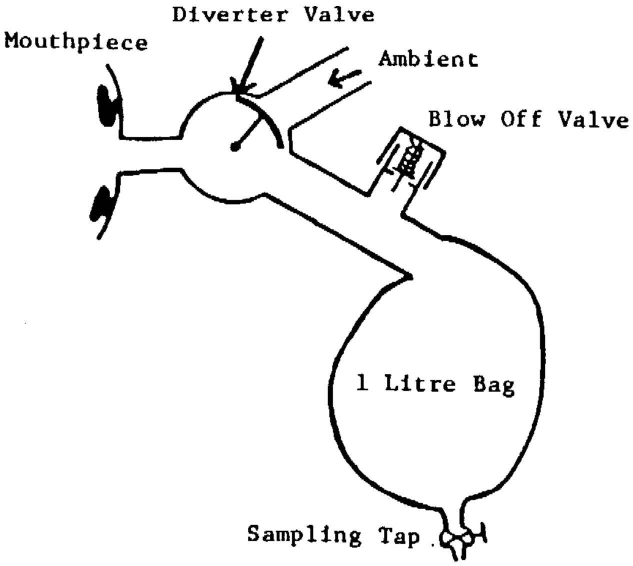
Depth of starting ascent	**0**	**10 (33)**	**15**	**(48.5)**	**20**	**(66)**	**30**	**(99)**
Depth of oxygen exhaustion	0	0	0	0	0.75	(2.5)	4.8	(16.0)
Depth PO_2 equals 40 mm Hg	0	Not applicable	1.8	(6.0)	3.3	(11.0)	8.2	(27.2)
Depth PO_2 equals 70 mm Hg	0	Not applicable	3.3	(11.0)	4.8	(16.0)	9.4	(31.0)

Depths are given in metres and in (feet) of sea water. The lung volume is assumed to be FRC (2.9 litres) at the start of the ascent and ascent rate 30 m (99 ft) per minute.

Employing a double lock chamber the divers were in turn taken to the test depth where they worked on a bicycle ergometer for a period of 5 minutes at light load to achieve steady state. The load selected was comparable to swimming at 22m (75 ft)/min and was a comfortable one. At a prearranged signal the diver was switched to a very limited volume partial rebreathing circuit (Figure 3) and 3 seconds later the ascent commenced at as near 30 m (99 ft)/min as possible. When the ascent began the diver increased his exertion to a level which had been determined by closed circuit spirometry to represent an O_2 consumption equal to the cost of ascent while neutrally buoyant.[8] There is great merit in the argument that in this situation the diver would be attempting considerably greater speed but we selected this speed because it is the most efficient with regard to time and O_2 cost. O_2 cost becomes increasingly exponential with speeds above 30 m (100 ft)/min and thus the effect would be to bring on critical hypoxia at greater depth

FIGURE 3

REBREATHING EQUIPMENT DIAGRAM



howbeit more rapidly. During the ascent the diver had two simple tasks, first to keep his output or speed constant and second, to produce a regular repetitive tapping with a metallic object.

Failure or irregularity in the performance of either of these tasks was noted against depth by an outside observer while the tender in the lock was prepared to close the valve on the rebreather bag to retain an expired gas sample at the failure point and administer O_2 if necessary.

The partial rebreathing circuit was employed because of the potential for embolisation due to small airway closure if continuous exhaling routines were used. It also served to provide a source of expired gas samples, which due to the rapid rebreathing could safely be considered to represent an end expired gas sample essentially in equilibrium with alveolar gas tensions, and consequently gas levels, with only a slight lag.[9]

In addition to direct equipment and physician availability, the main lock of the chamber was held at 60 m (200 ft) throughout so that a very speedy dive to 50 m (165 ft) could be effected if required.

Unlike the theoretical diver the subjects had the advantage of retaining 1.0 litre of their expired gas and being able to rebreathe it. It is difficult to calculate accurately how great this advantage was in ml O_2 but it essentially increases the FRC by 1.0 litre and consequently reduced the loss due to expansion during the ascent. It gave the experimental subject a significant edge over the hypothetical diver.

When the end point was reached, as determined by complete failure of one or other of the primary tasks or in one case, because of unconsciousness, the tender would trap the last expired gas sample in the rebreather bag by closing the valve and the gas was then analysed at the surface for O_2 by Ohio O_2 meter model No 601 with modified scale expansion and for CO_2 by modified Campbell Haldane apparatus. The results, corrected for depth and BTP, are shown in Table 3.

TABLE 3

CHAMBER TESTS AVERAGE OF THREE RUNS AT EACH DEPTH (SUBJECTS R AND H)

Starting depth	9 (30)	13.6 (45)	13.6 (45)	18 (60)	18 (60)	27 (90)	27 (90)
Subject	R and H	R	H	R	H	R	H
Depth difficulty began	Not applicable	3(10)	4.5 (15)	6 (20)	6.3 (21)	10.3 (34)	2.1 (7)
Depth terminated	0	1.2 (4)	2.1 (7)	3.6 (12)	2.4 (8)	*2.7 (9)	3 (10)
PO_2 mmHg at termination	Not applicable	48	48.4	60	55	47	56
PCO_2 mmHg at termination	Not applicable	47.7	53.5	72	81	71	58

Depths are given in metres and (feet). * denotes the subject went unconscious.

Discussion

Although the number of ascents and subjects is small, the results showed that the subjects became critically hypoxic before reaching the surface in all cases starting deeper than 13.5 m (45 ft) and that the depth at which this occurred, moved down slightly with deeper dives in accordance with the prediction.

We made no attempt to predict the course of the CO_2 and were surprised at its marked rise in many of the ascents. This rising CO_2 would enhance O_2 release from the haemoglobin, but would add to the cerebral dysfunction caused by the hypoxia.

The subjects were aware of fixation of purpose during the latter phases of all runs and this parallels reports by divers who made such ascents. Some of these have reported amnesia for the final portion of the ascent consistent with critically low O_2 levels.

Fortunately most sport divers at this time are using buoyancy compensators or other flotation devices which will passively expand as the diver ascends, eventually resulting in buoyancy assistance during the ascent without specific action on the part of the diver. This fact has probably saved more than a few lives.

Unfortunately it is required that the diver accomplish some variable portion of the ascent for this to occur and hypoxia comes on without warning so that there may no opportunity for the diver to take action to alter his buoyancy at the critical instant.

The O_2 cost of the same ascents, accomplished at the same speed by buoyancy alone, is much less.

The surplus O_2 provided by this method is an obvious advantage which must be weighed against increased risk of air embolism or decompression sickness due to uncontrolled ascent or inappropriate techniques. We believe training can minimise these.[9]

Conclusion

This information clearly needs to be taken into account when devising responses for the out of air situation. The diver needs to ensure that he has the ability to render himself positively buoyant in any ascent which may result in hypoxia or loss of consciousness from any cause. This has been borne out by the statistics in our experience (Table 1).

Alterations in the amount of O_2 available can be achieved by increasing the lung volume during ascent, decreasing exertion, and use of alternate air supplies. We feel that further study is needed in this area to clarify the issues involved. Ascents from depths of 36 m (120 ft) are planned with a refined protocol.

References

1 *Emergency Ascent Training.* Bethesda, Maryland, UMS Report, December 1977.

2 McAniff, John J. *US Underwater Diving Fatality Statistics 1970-1979*. URI, Report No. URI-SSR-30-14.

3 Registrar General, Province of Ontario, *Statistics 1982*.

4 Kory, Dalfahan, Boren and Syner. *AM J Med* 1961; 30: 243-58.

5 Estimated distribution of blood in the vascular system of a hypothetical man, age 30, weight 63 kg, height 178cm, assumed blood volume 5.0 litres, Table IV. Barker et al. *Medical Physiology*. Philip Bard, 10th Edition, 1956, p 43.

6 Craig, A.B. Jnr, Ware, D.E. Effect of immersion in water on vital capacity and residual volume of the lungs. *J. Appl. Physiol*. 1975. 38:449-454.

7 Lanphier EH. *Oxygen Consumption in Underwater Swimming.* US Navy Experimental Diving Unit, Washington DC. 1954. Formal Report 14-54.

8 Tobermory Hyperbaric Unit. Vest trials. Unpublished data.

9 Gas tensions in alveolar air (simultaneously estimated by five different procedures) and in arterial blood (directly determined): mean values in 11 normal young men at rest at sea level. Barker et al. *Medical Physiology*. Philip Bard, 1956, 10th Edition. p 296, Table XV.

This paper has been in the hands of the SPUMS J. since March 1983. A letter in September 1984, asking Dr. Harpur whether the long interval had altered his views and whether he had any objections to its being published produced the following reply.

To answer your questions quite simply, no, I have not encountered anything which would persuade me to alter my views since that paper was completed, and no, I do not have any objection to it being published. Our experience since that time, has if anything reinforced the views expressed, and I am happy to report to you that whether entirely due to the adoption of the principles outlined in the Ascent Protocol you published earlier (SPUMS J. 1982; Oct-Dec: 32-38), or to improved instruction, we have seen a drastic reduction in diving accidents and fatalities in our particular region over the past three years. We were reluctant at first to call this a definite trend, but it has been consistent enough that we are now quite certain it is. This has had the somewhat unfortunate effect of reducing our opportunities for expanding clinical experience, as the bulk of the difficulty now encountered centres around sinus and ear squeeze.

Yours sincerely
G.D. Harpur

We are sure that all our readers would like to be able to quote similar statistics for their region !

Dr. Harpur recommended (*SPUMS J*. 1982; 12 (Oct-Dec): 32-39) a continuous breathing cycle for out of air ascents. The points are

1. Do NOT remove the regulator from your mouth unless you have another to replace it with, or in cases of entanglement. The regulator provides a safety valve and a possible source of air.
2. Continue to attempt to breathe in and out at all times even if out of air or without your regulator. This ensures an open glottis and larynx and minimises the chance of small airway closure.
3. Make certain you are positively buoyant by inflating your buoyancy compensator or dropping the weight belt or both. This guarantees that you will reach the surface despite hypoxia.

Dr. Harpur also emphasised that CPR training was the most critical factor, in the accidents in the Tobermory region, in determining the outcome if the diver surfaced. Good dive organisation ensured rapid response and prevented incidents from becoming complicated.

The address of G.A.D. Harpur and R. Suke is the Tobermory Hyperbaric Facility, Tobermory, Ontario, Canada.

A LETTER FROM IRELAND

Gerry Stokes

Once again this Phoenix is raised from the ashes. I would have thought that everyone would have solved this problem in their own way by now. You posed three questions at the start of your article and the answer to them is yes it is necessary, yes it is effective, and yes it is dangerous.

You will note that all the “Rescue Apparatus” that equipment manufacturers brought out are in themselves mechanical, all of which can go wrong. A free ascent has nothing mechanical to go wrong. Yes it is necessary.

You seem to suggest that it is a common occurrence for divers to surface with completely empty tanks. This is madness!!! Where do these people learn to dive. In Ireland you are expected to surface when your air reaches reserve (50 bar) and if you have less than that questions are asked.

The only out-of-air situation we train for is mechanical failure and towards that end we recommend one of three methods. Octopus regulators including Air II, buddy breathing and free ascent, not necessarily in that order but each diver is taught all three methods and all are practised in the pool during training.

When you think about it, the first time you realise you are out of air is after exhalation when you inhale and nothing happens. Your first reaction should be to use your octopus regulator or Air II, if you have one. If not look for your buddy to share his air, but if his is too far away (i.e. it will take you as long to get to him as it would to get to the surface) then it is recommended that you drop your weight belt and swim for the surface. At least an embolism can be cured, it is difficult to cure a drowning.

You mention the debate between the medical faction and the instructor faction, well I have not heard how it goes with you, but I think there could not be much between them. The faction that differs greatly is the recreational diver faction. These people seem to want to know nothing about the problems. The proper concept of emergency ascent training should not be watered down, thinned out, or made look simple just for these people. There should be one solution for all and it should be comprehensive.

With the more common use now of octopus regulators and Air II, free ascents and buddy breathing are gradually being pushed back along the priority line but nevertheless every diver should be taught the techniques. In Irish diving we teach and practise free ascents quite successfully. To date we have not had an accident while training or practising. Initially it is taught while swimming in the pool with the regulator always in the mouth, in the sea it is practised up a shot line accompanied by an Instructor with a safety diver at the stop depth. One thing we do not recommend is changing methods on the way up. Whatever method you start with go all the way to the surface with. A number of years ago we had two accidents, not too far apart in time, where two divers buddy breathed from around 25m up to 10m-8m, in both cases the victim then did a free ascent and never reached the surface alive.

I think carrying SPARE AIR in any form is of little use, the reaction time is so short divers even forget to drop their weight belts. All the extra equipment a diver now carries is getting dangerous, too many times, all added weight and more serious bulk.

Every diver should be taught self preservation techniques, that is how he, on his own, can get from the bottom to the surface, alive. The effectiveness of emergency ascent training can be judged by the amount of time and consideration each diver gives to learning about it, which brings us back to the attitude of the instructors, and back further to the attitude of the training agencies, or dive shop or club. As was correctly mentioned in an article in the

SPUMS Journal, we now have two kinds of amateur divers, sports diver and recreational diver.

Sports divers will want to know and learn proper emergency ascent techniques and will train for the eventuality.

Recreational divers do not have the same interest in the technicalities of diving and leave "all that" to their instructors and dive masters seemingly with the attitude "They'll get me out of any problem, that what they are there for." These are the people with a little knowledge that is dangerous. It is to facilitate this new recreational diver that well tried and tested methods of good dive practice are being whittled away. Old reliable safety procedures which sports divers learn and train for are too strict and take too long to learn (normally a separate course) for the recreational diver. They only want to dive during the holidays so these safety procedures are watered down or dropped or replaced with another piece of equipment that is "easy" to use. But !! What about the divers mental attitude to the environment he is in or the emergency situation he is likely to be in ? This mental adaptation only comes with training and experience. To facilitate the recreational diver the word "Danger" has been dropped or at least well watered down in the divers vocabulary. The real meaning of the word is still there as large as life, waiting to happen at the least expected time.

The medics can see the dangers and so can the instructors but some of these people shield the divers from it. When accidents happen, as they do, the divers are genuinely surprised, nobody told them it would be like this. The workshop which you are organising should be aimed at people who want knowledge, medics, instructors and sports divers. The information, suggestions and conclusions should be given out with these people in mind. Let the responsibility for the information rest with them. Most of them are responsible people, let them use the information wisely.

Some points I think the workshop, should cover:

1 The medical implications of each kind of ascent discussed.

2 A recommended maximum rate of ascent for each kind of ascent discussed.

3 The free ascent must be considered as the only non-mechanical option. Consider the diver with no mechanical option available to him.

4 The consequences of emergency ascents should be itemised with likely illnesses, symptoms, treatment.

5 The psychological attitude of each kind of diver likely to be in an emergency ascent situation, instructor/dive leader, sports diver, recreational diver, trainee diver. All to be considered in the light of their experience and training.

I will be looking forward to reading the report of this workshop. Some years ago the UHMS ran a workshop in Bethesda but did not really come to any firm conclusions at the end. I hope this one will be a little more positive.

Have a good, enjoyable conference.

Mr Gerry Stokes is a member of the Irish Underwater Council. His address is 78A Patrick Street, Dun Laoghaire, County Dublin, Ireland.

A LETTER FROM ENGLAND

The following has been extracted from a letter, dated 19/2/93, to Dr Des Gorman, the convener of the 1993 SPUMS Annual Scientific Meeting, from Surgeon Commander James Francis, Senior Medical Officer (Diving Medicine), at the Institute of Naval Medicine, Alverstoke, Gosport, Hampshire PO12 2DL, UK.

"Thank you for your letter dated 8 February enquiring about SETT (submarine escape training tower) reports. The Standing Committee on Submarine Escape and Rescue (SCOSER) has recognised that even the most recent report is now dated and so it is hardly surprising that your request is serendipitous, Peter Benton and I are currently reviewing the data again and intend to publish a new report.

It will be very different to previous reports in that it will be manifestation-based and no assumptions with respect to the nature of the illnesses which the escapers and instructors suffered will be made. Already, this approach is throwing up some interesting observations: not least, that pulmonary barotrauma (based upon hard signs and investigation results) is nothing like as common as has previously been assumed. This approach will mean that there will be a large "unknown" category in the analysis which will contain the cases in which it is not possible to be confident of what, if anything, went wrong."

A LETTER FROM AUSTRALIA

The following is an extract from a letter sent by Dr. John Williamson, the Director of the Hyperbaric Medicine Unit at the Royal Adelaide Hospital, to Dr Des Gorman, the Convener of the SPUMS 1993 Annual Scientific Meeting, as a contribution to the Emergency Ascent Training Workshop. It had been originally written in response to a query from the Queensland Diving Industry Workplace Health and Safety Committee.

Emergency Swimming Ascent Training (ESAT) vertical ascent training and multiple dives by instructors

1 The risk of Emergency Swimming Ascent Training (ESAT) is essentially two-fold;

a Decompression illness
b Pulmonary barotrauma

The risk of “reverse squeeze” is present, but the incidence appears to be low.

Multiple ascents on a single dive modify, in an unpredictable manner, the kinetics of inert gas clearance from body tissues, in favour of the development of decompression illness.

2 In my opinion (and based partially on my own experience between 1978 and 1983 as a practising PADI open water instructor), it is better to have practised any skill (including ESAT) at least once before having to do it in anger. There is analogous data from resuscitation training that supports this contention, but I know of no firm data either way, relating directly to ESAT.

It should be appreciated that no student does it once only. It is done, as is “buddy breathing ascent” and “octopus ascent”, once only in open water. It is practised several times in swimming pools beforehand. This prior pool practice is essential.

3 These practices have been applied, in Australia alone, to hundreds of thousands of student divers. Where are all the injured patients? I find it difficult to advocate curtailing the activity in the face of such admittedly circumstantial evidence. However my understanding of diving medicine causes me to urge strict practice codes for such training. I should be happy to discuss them if you wish, but these are my opinions only.

I believe “horizontal ascent training” is a poor (and not necessarily safe) alternative to ESAT. The concept that ESAT implies a rushed ascent is false.

4 It is the dive instructor who is a maximum risk. However 32 ascents a day is totally unacceptable, medically speaking and is unnecessary. In my view (and after some consultation) there should not be a necessity for an instructor (or his assistant) to do more than 10 ascents from a depth greater than 5 m during any single day with a student class (maximum 10 students). Even that number of ascents is medically undesirable, but difficult to reduce. The maximum depth of the entire dive should be 5 m or less. The dive must not be a repetitive dive. The practice of conducting multiple open water classes with more than one student group on the same day is to be deprecated. I know it happens.

The use of the divemaster or the assistant instructor to do an equal share of the buddy breathing and octopus ascents is essential. I know at present PADI says only the Instructor can conduct the ESATs.

This approach would mean that each of the Divemaster/Assistant Instructor and the Instructor would conduct 10 ascents in 24 hours (excluding the snorkel dive), in a week-end open water dive course. Conducting the open water component of the course over 2 weekends would be safer, but will be opposed.

5 There is no hard data, except to say the fewer ascents above a total of 1 per dive, the better. However, slowly, painfully, and with the efforts of my colleagues in this Unit, the DAN Australia and DIMS (Diving Incident Monitoring Study) data is accumulating. Some meaningful data should emerge in the next 5 years.

A LETTER FROM THE U.S.A.

Larry Williamson

One of the first issues I would like to address is that I think it is a mistake to take an either or approach. Even when there have been rare occurrences of wide spread agreement on what could be best for people, no single solution or technique works every time. So the question should be, not what to throw away but what system is the most likely to be successful and then give that system the most support and give the other options their appropriate levels of support based on their own merit.

During discussions such as this people sometimes point to past results to determine what should be done next. During a recent (May/June 1993) NAUI Sources Forum, the debate focused on “Should Buddy Breathing be discontinued?” The majority said “No” citing such things as many lives were saved in the past because the skill was taught. However, the person saying this did not include how many died while unsuccessfully attempting buddy breathing. But even if they did include all of the past facts, the problem is that they all come from the past and are thereby incomplete or slanted by all of the other events that influence people’s actions that were also at work in our culture. We should remember that no one who knew anything about history or current events regarding the relationships between countries predicted that the Berlin Wall would suddenly disappear without a shot being fired. The

Berlin Wall fell because there were people who were working on the future who were able to gain some freedom from their own past and stand in the question of “what could happen?” I invite us to imagine that right now we are in the year 2010 and we are looking back to the year 1993 and then ask ourselves if that was the time we began to address issues such as Diving Safety, Free Ascent Training, and Redundant Breathing Systems accurately and free from the past’s distortions? Did we realign our training resources, based on what would give each person the best chance for survival, or did we keep on saying things like all “alternate air sources” are alike, pick anyone you want?

You may have wondered when my own personal bias would show up, here it is. There can be little room for advancement until the diving community can distinguish between true redundant systems such as SPARE AIR and Pony Bottles vs. octopus or so-called safe seconds. I think that this omission keeps diving in the dark ages as compared to other sports. Can you imagine how Sky Diving would be viewed if their instructors went around saying spare chutes are a good idea but you don’t need one for yourself as long as your buddy has one and that you both jump from the same plane. Of course, it sounds ludicrous but after 13 years of SPARE AIR, Pony Bottles and octopus’s all being available today’s new diver is being told that their value to him are all the same.

Every training agency that I am aware of has a statement that goes something like this “without making specific recommendations we do support the use of all alternate air systems i.e. safe second, pony bottles and/or redundant systems”. I believe such statements are gross errors of omission from a past directed viewpoint and all of its limits. Such omissions help perpetrate misconceptions of future divers. After all, they would expect really important safety information to be clearly stated. They would believe that the experts and the Great Leaders of Diving would have given them all of the important facts. When they read that **all** alternate air supplies are the same they would tend to believe it and later pass on the same myth.

What do I propose? I don’t want any laws passed that make people buy SPARE AIR, nor do I want every training agency’s specific endorsement. I do however believe that all who are the leaders in diving should do their very best to fully inform future divers of the distinctions and give all divers the right to do a free and informed choice.

I learned to dive in 1972 and was taught one free ascent from 15' (4.5 m) and the buddy system was supposed to be my final backup to any diving safety concern. I was told to practice free ascents on my own. This I did several times and reached a point of being able to come up from 50' (15 m) and even 60' (18 m) with some comfort and confidence. But then one night my buddy and I were chasing lobsters at 140' (42 m) and swimming at top speed, when suddenly I was out of air. I looked for my buddy and saw his light way above me heading for the surface. He has run out of air just a few seconds before me and had no time to warn me. Needing air more badly than ever before in my life I started up. I estimate that I ascended to a depth of 70' (21 m) before I blacked out. Just before blacking out I realised that I was just one breath short of making it back alive. One small breath held the power of life or death over me and yet none were available to me. I also realised that if someone had tried to sell be one extra breath just before my dive that I would have looked him in the eye and said “I won’t ever need it, I use the buddy system, and have practiced free ascents”. Looking from my past my whole life showed me that I would probably never run out of air at a depth that I couldn’t get back up from. Now too late I realised my error and that even though I would now pay any price for just one breath, it was just too late. My last action was to pop the CO_2 cartridge on my buoyancy compensator. I did reach the surface unconscious and was later revived. Of course, I never forgot that experience.

When I started Submersible Systems and began to make and sell SPARE AIR I knew it would be an uphill battle because I would be talking to people just like me who would say “I probably won’t ever need it, after all I haven’t drowned before etc. etc. “ I have always known that even if all divers were given the opportunity to make a completely informed choice to carry a redundant system that some still would chose not to do so.

So I see my job is to help give them that choice, the choice to enhance their ability to rescue themselves. Progress continues to be made. Just this last month we received 3 letters from divers thanking us for saving their life with SPARE AIR. I am always thankful for such letters because I know that I didn’t save their life, they did, I only helped give them the choice.

In closing, I again invite everyone in this conference to stand out ahead in the year 2010 and look back at 1993 and ask what did we give all those thousands of people who came after us. Did we begin to point out that an emergency ascent with a redundant air supply has the best chance of success, followed by a distant choice of trying to find someone else’s octopus or did we say that the octopus was tied with practicing emergency swimming ascents and that a still distant 3rd recommendation was buddy breathing? Hopefully we will explain every option clearly and remind people that it is highly probable that you will not get a second chance about this decision, so make your decision clearly.

Finally, thank you for the opportunity to speak to you for I feel each and every person can made a small individual contribution to the outcome and that it is possible for this group to be the start of something for the future.

Mr Larry Williamson is President of Submersible Systems Inc. of 18112 Gothard Street, Huntington Beach, California 92648, U.S.A. He was unable to attend the Workshop but sent his paper. Submersible systems Inc. generously provided sponsorship for the SPUMS 1993 Annual Scientific Meeting.

CURRENT PHILOSOPHY AND PRACTICE OF EMERGENCY ASCENT TRAINING FOR RECREATIONAL DIVERS

Drew Richardson

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

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

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

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

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

TABLE 1

INJURIES IN VARIOUS SPORTS

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

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

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

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

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

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

History of present policies on emergency ascent procedures

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

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

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

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

Defining emergency ascent

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

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

TABLE 2

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

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

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

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

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

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

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

Defining Options

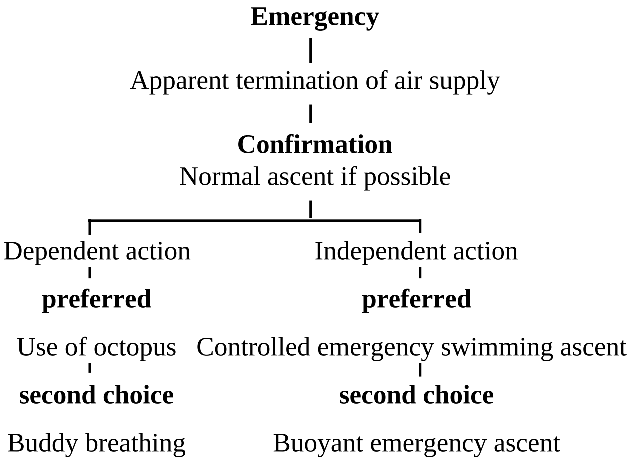
Emergency ascents to the surface (which generally are the result of a low air situation) may be handled in several ways depending on the circumstances of the incident. Whenever possible, a direct swimming ascent, with the mouth-piece in place, is desirable. This usually will allow the diver to draw additional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

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

FIGURE 1

FLOW CHART FOR OUT-OF-AIR EMERGENCIES

Based on NSTC policy on emergency ascent procedures
April 1977



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

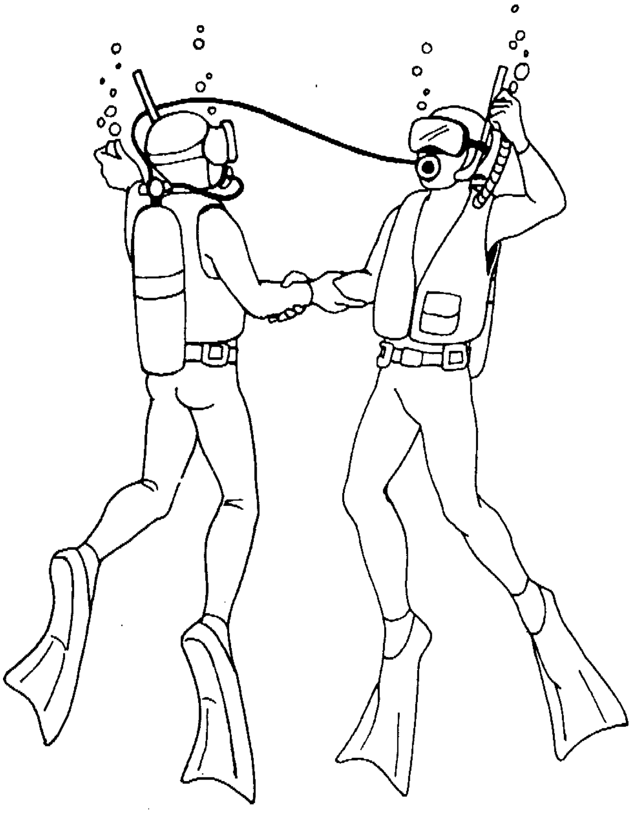
Dependent options

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

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

FIGURE 2

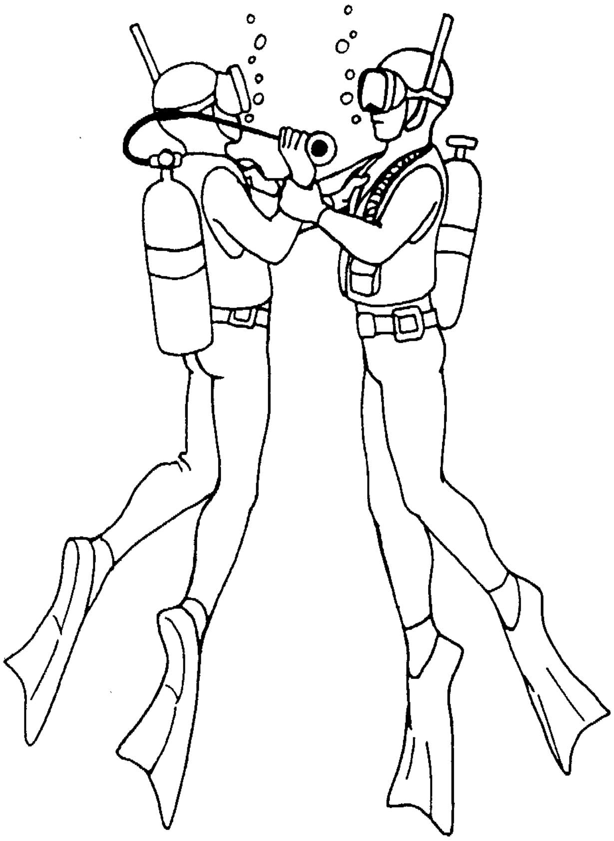
ALTERNATIVE AIR SOURCE



Source NAUI Openwater 1 Scuba Diver Instructor Guide 1987

FIGURE 3

BUDDY BREATHING



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Independent options

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

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

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

Procedures

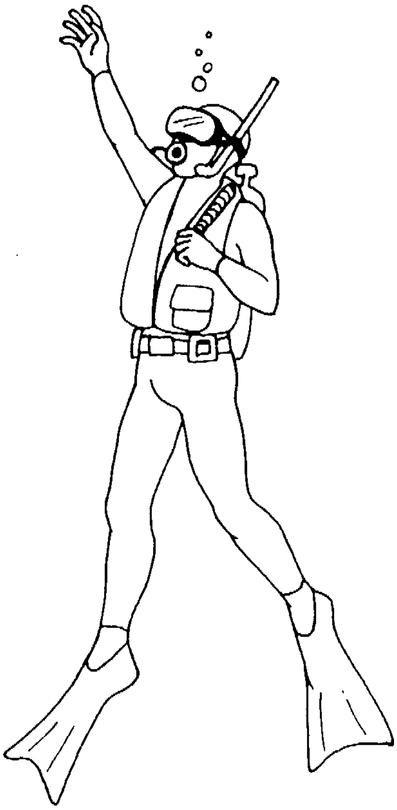
Emergency ascent training methods have been improved and refined over the course of time. The manner and the conditions in which training is conducted are important. Before engaging in this training students are preconditioned to reduce stress. Unfavourable environmental conditions are avoided when the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

NORMAL ASCENTS

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

FIGURE 4

CONTROLLED EMERGENCY SWIMMING ASCENT



Source NAUI Openwater 1 Scuba Diver Instructor Guide 1987

FIGURE 5

BUOYANT EMERGENCY ASCENT

Source NAUI Openwater 1 Scuba Diver Instructor Guide 1987

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

ALTERNATIVE AIR SOURCE ASSISTED ASCENT

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

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

CONTROLLED EMERGENCY SWIMMING ASCENT

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

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

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

BUDDY BREATHING WITH A SINGLE REGULATOR

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

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

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

BUOYANT EMERGENCY ASCENT

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

BUDDY TEAMWORK

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

Summary

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

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

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

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

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

References

1 *1990 Report on Diving Accidents and Fatalities*. Durham, North Carolina: Divers Alert Network, 1992

2 Acott C. Scuba diving incident reporting: the first 125 incidents. *SPUMS J* 1992; 22(4): 213-220

3 *1991 Report on Diving Accidents and Fatalities*. Durham, North Carolina: Divers Alert Network, 1992

4 Curry A. Diving medicine in Micronesia 1991-1993. SPUMS J 1993; 23 (4): 240-243

5 *NAUI Pro Manual*. Montclair, California: National Association of Underwater Instructors, 1984

6 *PADI Instructor Manual*. Santa Ana, California: Professional Association of Diving Instructors, 1990

7 *SSI Instructor Manual* 1149 Riverside Drive, Fort Collins, Colorado 80521: Scuba Schools International, 1987

8 NAUI, PADI, NASDS, YMCA and SSI. NSTC Ascent Agreement. *Pressure* 1976; 5

9 *The Fifteenth Undersea Medical Society Workshop* Samson RC and Miller JW eds. Bethesda, Maryland: Undersea Medical Society, Inc., 1978: 31-32

Bibliography consulted

Bennett PB and Elliott DH. *The Physiology and Medicine of Diving (Third Edition)*. San Pedro, California: Best Publishing Co., 1982:38-39

Brown CV. Emergency ascent training. *Pressure* 1976; 5

Brown C. The Medical Editor's column. *NAUI News* 1975; (November/December): 15

Davis JC. Causes of decompression accidents in sport scuba diving. *Hyperbaric and Undersea Medicine* 1981;1 (25): 2-4

Egstrom G and Bachrach A. Diver panic. *Skin Diver* 1971; 20 (11): 36-37, 54-55

Graver D. NSTC agrees on emergency procedures. *PADI Training Bulletin* 1977; 77-2: 2

Graver D. In support of emergency ascent training. *Addendum to the Proceedings of the Eighth International Conference on Underwater Education* Colton, California: National Association of Underwater Instructors, 1976: 16-26

Graver D. NSTC policy on emergency procedures. *PADI Training Bulletin* 1977; 77-2: 2-3

Graver D. Emergency ascent standards changes. *The Undersea Journal* 19 ; 9 (1): 4-5

Hardy J. Emergency ascents. *NAUI News* 1971; (July): 2-3

Hardy J. Ascents. *Proceedings of the 7th International Conference on Underwater Education* Colton, California: National Association of Underwater Instructors, 1976: 186-191

Hardy J. Ascent training - NAUI policy on ascent training. *Pressure* 1976; 5 (5):

Hardy J. Emergency ascents. *NAUI News* 1976; March: 4-7

Hardy J. Ascent training. *Pressure* 1976; 5 (3): 10-11

Icorn N. Emergency ascent training. *Undersea Journal* 1972; 5 (3): 2

Harper GD. A new approach to out-of-air ascents. *SPUMS J* 1978; 8 (3): 14-17. This paper was written for but not published in *The Fifteenth Undersea Medical Society Workshop, Emergency Ascent Training*. Samson RC and Miller JW eds. Bethesda, Maryland: Undersea Medical Society Inc., 1979

Kindwall EP. Advantages and Disadvantages of Emergency Ascent Training. *Proceedings of the 7th International Conference on Underwater Education*. Colton, California: National Association of Underwater Instructors, 1976: 252-256.

Kindwall EP. Advantages and Disadvantages of Emergency Ascent Training. in *The Fifteenth Undersea Medical Society Workshop, Emergency Ascent Training*. Samson RC and Miller JW eds. Bethesda, Maryland: Undersea Medical Society Inc., 1979: A5-A9

Nemiroff MJ and Dircks JW. The hazards of sport diving free ascent training. *Proceedings of the 7th International Conference on Underwater Education*. Colton, California: National Association of Underwater Instructors, 1976: 358-365. Reprinted in *The Fifteenth Undersea Medical Society Workshop, Emergency Ascent Training*. Samson RC and Miller JW eds. Bethesda, Maryland: Undersea Medical Society Inc., 1979: 49-56

Richardson TA. How to teach the controlled emergency swimming ascent. *The Undersea Journal* 1987; Fourth Quarter: 40-44

Somers LH. Emergency ascent training: safe or unsafe. *Proceedings of the 8th International conference on underwater education* Colton, California: National Association of Underwater Instructors, 1976: 432-433.

Somers LH. *The Emergency Ascent Dilemma*. Michigan Sea Grant Reprint, July 1980. Appeared before publication in *The Fifteenth Undersea Medical Society Workshop, Emergency Ascent Training.* Samson RC and Miller JW eds. Bethesda, Maryland: Undersea Medical Society Inc., 1979: 57-79

Shilling CW. *Submarine Escape - An Annotated Bibliography.* Washington, DC: The George Washington University, 1972: 1-29

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

Chris Acott

Introduction

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

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

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

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

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

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

TABLE 1

HARMFUL INCIDENTS FOLLOWING OUT-OF-AIR ASCENTS

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

Experience

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

TABLE 2

QUALIFICATIONS

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

Causes and contributing factors

Not all the incidents had a recorded cause. Table 3 lists the identified causes of the out-of-air problem while Table 4 lists the associated contributing factors and Table 5 the contributing factors in those coming to harm. Many incidents had more than one contributing factor. This was commoner in those incidents resulting in harm

TABLE 3

CAUSES OF OUT-OF-AIR SITUATION

Did not check contents gauge regularly	24
Inaccurate contents gauge	16
Unable to read contents gauge	2
Free flowing 2nd stage	5
Air not fully turned on	5
First stage problem	4
Air used frequently to maintain buoyancy	4
Ruptured air hose	3
Kinking air hose (Hookah)	2
Total	**65**

TABLE 4

CONTRIBUTING FACTORS

Error in judgement/incorrect decision	30%
Failure to check equipment	29%
Inexperience in diving	29%
Inattention	20%
Malfunction or failure of equipment	18%
Total	**126%**

Discussion

A calibrated contents gauge is essential for safe diving. Contents gauge inaccuracy featured in 20% of the out-of-air situations. This is a disturbing figure. Contents gauges are not often serviced once purchased. Regular calibration, once a year, should be done. Because a diver needs an air supply at all times underwater, it may be wise to have a back up system. A sonic reserve in the pillar valve of the cylinder has been proposed[4] as a warning of a low air situation. New computer technology will enable all air data to be displayed at the diver's wrist with the contents sensor part of the 1st stage. However, the diver still has to look at the gauge on his or her wrist!

TABLE 5

CONTRIBUTING FACTORS AND HARM

Error in judgement/incorrect decision	44%
Inexperience in diving	39%
Insufficient training	28%
Poor communication	22%
Failure to understand equipment	22%
Failure to check equipment	22%
Total	**177%**

Using the power inflator to maintain buoyancy appears to be a problem associated with experienced divers. Failing to check their contents gauges frequently enough affects both inexperienced and experienced divers. These two causes accounted for 34% of the out-of-air ascents.

Infrequent checking of the contents gauge and frequent activation. of the power inflator for buoyancy control indicates poor diving technique.

Problems associated with hookah diving can be simply solved by the use of a “bail out” bottle. However, these bail out bottles should be checked and serviced in the same manner as the regular supply.

Malfunction or failure of equipment was a result of a lack of suitable servicing and calibration.

Failure to check, failure to understand, errors in judgement and inattention are human errors and can be corrected by appropriate training, as can insufficient training.

Action taken

In the 82 incidents, in which all reached the surface, 40 shared an octopus regulator, 16 buddy breathed and 26 ascended without an air supply. Of these twenty six, 21 reported that an alternative air source (pony bottle etc.) would have helped the situation.

Controlled Ascent

Fifty (61%) of the out of air problems did not involve a rapid ascent to the surface. These resulted in 3 cases of salt water aspiration. Of these 50, 17 ascended to the surface without help with one diver aspirating salt water. Of the remaining thirty-three, 27 involved an ascent with an octopus and 6 buddy breathing. Two of these ascents resulted in salt water aspiration (one octopus breathing, and one buddy breathing). These results indicate that a controlled non-breathing ascent has a morbidity rate at least equal to that of an ascent using an octopus or buddy breathing, but more data are needed. Table 6 provides a summary.

TABLE 6

OUT-OF-AIR WITH A NORMAL ASCENT

Number	Method	Complications
17	Unaided ascent	1 SWA
27	Octopus breathing	1 SWA
6	Buddy breathing	1 SWA with complications
50	**Total**	**3**

Rapid Ascent

Of the remaining thirty-two who made a rapid ascent to the surface, 18 (56%) ascents resulted in harm (Table 7). A rapid ascent increases the morbidity from 6%. (3 out of 50) to 56% (18 out of 36).

A rapid ascent breathing from an octopus invoIved a 26% chance of causing harm, while a rapid buddy breathing ascent involved a 50% chance (Table. 8). All the rapid, uncontrolled non-breathing ascents (i.e. neither octopus nor buddy breathing) involved morbidity.

TABLE 7

OUT-OF-AIR WITH RAPID ASCENT

All ascents		**32**
Harmful		**18**
Decompression illness	9	
Cerebral arterial gas embolism	4	
Pulmonary barotrauma with CAGE	1	
Pulmonary barotrauma	2	
Salt water aspiration	l	
Near drowning	1	

TABLE 8

RAPID ASCENTS AND HARM

Octopus ascents		**13**
Harmful incidents		**3**
Cerebral arterial gas embolism	1	
Pulmonary barotrauma	1	
Salt water aspiration	1	
Buddy breathing ascents		**10**
Harmful incidents		**5**
Decompression illness	3	
Pulmonary barotrauma and CAGE	1	
Near drowning	1	
Non-breathing ascents		**9**
Harmful incidents		**10**
Decompression illness	6	
Cerebral arterial gas embolism	2	
Pulmonary barotrauma	1	
Saltwater aspiration*	1	

* This diver developed decompression illness later, so having two harmful incidents due to running out of air.

Conclusions

From these data, a non-breathing slow exhaling ascent is associated with the same or less morbidity as a slow, aided (octopus or buddy breathing) ascent. However, as the ascent rate increases, so does the morbidity rate. This is true for both non-breathing and aided ascents. However, a rapid ascent breathing from an octopus is associated with a much lower incidence of morbidity than a buddy breathing or non-breathing rapid ascent.

If a diver is able to control his or her ascent rate then the chances of morbidity are reduced. The ability not to panic and to think about the task involved are significant factors in decreasing harmful incidents. Therefore, from the limited data presented, controlled exhaling ascents should be an important part of diver training.

References.

1 British Sub-Aqua Club. *Safety and Rescue for Divers.* London: Stanley Paul and Co Ltd, 1987

2 *PADI Open Water Diver Manual.* Santa Ana, California: PADI, 1990

3 Acott CJ. Diving Incident Monitoring: an update *SPUMS J* (in press)

4 Acott CJ, Sutherland A and Williamson J. Anonymous reporting of diving incidents: a pilot study. *SPUMS J* 1989; 19 (1): 18-22

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A TRAINING AGENCY PERSPECTIVE OF EMERGENCY ASCENT TRAINING

Drew Richardson and Terry Cummins

Emergency ascent training has been a controversial subject in recreational diving since the early 1970s.[1] The associated controversy revolved around techniques, psychological and physiological considerations and concern about the changing legal climate.

The Catch 22 is this: Is it wise and ethical to train divers in emergency ascent techniques, even though the training itself may provide some hazard, or to not train these procedures and have the lack of training itself provide the hazard? We would have a moral concern over any situation where a student would attempt a unsuccessful emergency ascent, having never been trained in the procedure. As diving educators, instructors must concern themselves with practical training so that students will dive safely without supervision after certification.

Diving accident statistics tell us that divers do indeed experience loss or interruption of air supply, despite our best instructional efforts, sometimes with less than satisfactory results.[2,3] For this reason, emergency ascent training has been included in every entry level scuba course since the inception of diving instruction. It was improved in the late 1970s and again in the early 1980s. Literally millions of safe ascents have been made by divers involved in training programs. More importantly there is no way for anyone to tell how many near misses occur or how often injury or death has been avoided by these techniques in the field.

15 years ago concerned persons got together to discuss emergency ascent training. They tried to develop a mutual understanding in order to improve the safety and training of divers. The proceedings from the 15th Undersea Medical Society Workshop on Emergency Ascent Training,[4] has been discussed in another paper in this issue[1] and that discussion will not be repeated here. These goals were achieved. It is an extremely positive sign that we are all gathered here today, for similar reasons, to continue this worthwhile process.

Despite misconceptions, sensationalism, and a lack of understanding in some quarters, indications support scuba diving as one of the safest sports.[1,2] From time to time, recreational scuba diving finds itself under scrutiny, because of the reckless habits of a few divers. Fortunately improper diving behaviour and poor decision making are not the norm for recreational scuba divers. By and large, divers and diving are becoming safer. This is largely due to significant improvements in the standards and training methodologies of the training organisations, as well as improvements in equipment technology.

What is the incidence of morbidity and mortality in emergency ascent training?

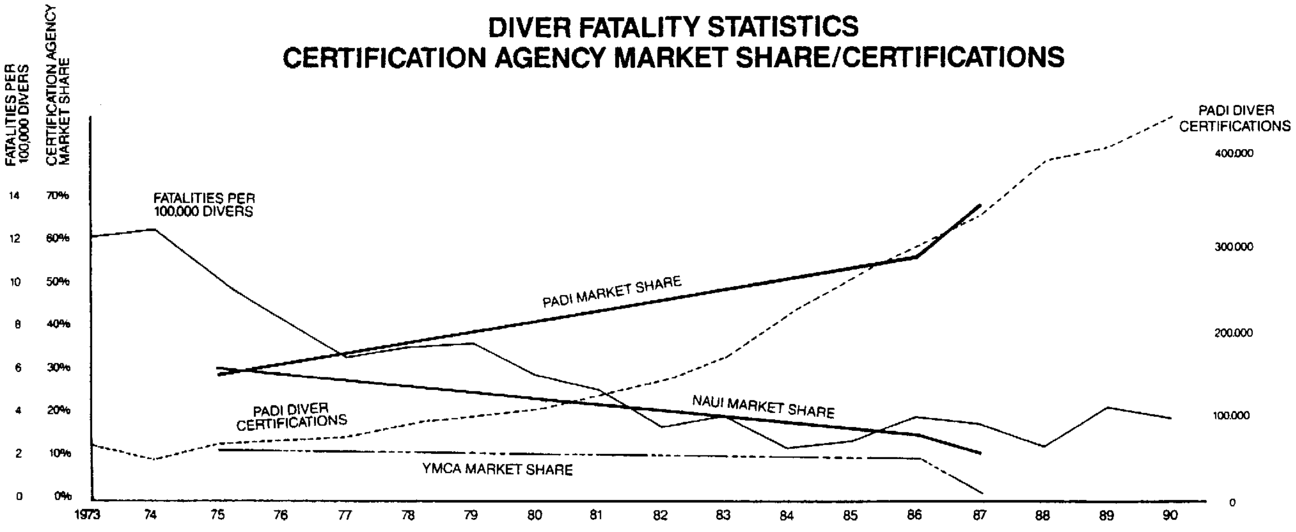
During open water training PADI requires three normal ascents and one buddy breathing ascent, one alternative air source assisted ascent and one controlled emergency swimmings ascent. The minimum number of emergency training ascents each individual performs (as required by standards for certification) is three. Table 1 shows the total number of PADI entry level certifications by year and the number of injuries and deaths for the period 1989-1992. It also shows the minimum number of

TABLE 1

MORBIDITY AND MORTALITY REPORTED DURING PADI EMERGENCY ASCENT TRAINING 1989-1992

Year	Entry level trainees	Emergency ascents	Injuries reported	Deaths
1989	276,065	828,195	8	-
1990	304,352	913,056	8	-
1991	319,708	959,124	7	2
1992	351,443	1,054,329	10	-
Total	**1,251,568**	**3,754,704**	**33**	**2**

FIGURE 1



MARKET SHARE SOURCES:
1975 - *Physiology & Medicine of Diving*, Bennett & Elliot
1986 - Harvey Research Org., Inc., *Skin Diver* 1987 "Subscriber Survey"
1987 - Calculated from "DEMA Blueprint for Growth"

FATALITY STATISTICS:
"U.S. Underwater Diving Fatality Statistics,"
National Underwater Accident Data Center (NUADC), University of Rhode Island (URI)

TABLE 2

MORBIDITY AND MORTALITY BY NUMBER AND TYPE OF INJURY DURING EMERGENCY ASCENT TRAINING 1989-1992

Injury	Controlled emergency swimming ascent	Buddy breathing ascent	Alternative air source assisted ascent
Ear	3 (1 ruptured drum)	1	2
Near drowning		2	1
Water aspiration		3	1
Squeeze			2
Embolism	4 (1 fatal)	3 (1 fatal [asthma])	2
DCI		1	
Nose bleed		1	
Admitted ICU			1
Chest pain		1	
Questionable embolism		2	
Panic (no injury)		1	
Hypoglycaemic convulsion	1		
Collapsed lung	1		
Total	**9**	**15**	**9**

TABLE 3

INCIDENCE OF REPORTED INJURY BY ASCENT METHOD

Method	Injuries	Ascents	%	Injuries per 100,000 ascents
Buddy breathing	15	1,251,568	0.00119	1.19
Alternative air source	9	1,251,568	0.00071	0.71
Controlled swimming ascent	9	1,251,568	0.00071	0.71
Total	**33**	**3,754,704**	**0.00087**	**0.81**

TABLE 4

INCIDENCE OF EMBOLISM OR LUNG OVER EXPANSION INJURY BY ASCENT METHOD

Method	Injuries	Ascents	%	Injuries per 100,000 ascents
Buddy breathing	5	1,251,568	0.00039	0.39
Alternative air sourc	2	1,251,568	0.00015	0.15
Ccontrolled emergency swimming	4	1,251,568	0.00031	0.31
Total	**11**	**3,754,704**	**0.00029**	**0.29**

emergency training ascents conducted by those trainees. This is a conservative number as it does not include the fact that instructors often have students switch roles from donor to receiver and repeat the ascent, and this does not reflect any remediation or repetition of the skill.

Table 2 shows the type and incidence of injury during PADI emergency ascent training, by method used, for the same period. This data may be considered as highly reliable. PADI instructors are obliged to complete incident and accident report within two weeks by PADI standards and also by a warranty of liability insurance coverage.

If a member neglects to report any incident and a suit is later filed, his insurance is rendered null and void. Quality assurance procedures are initiated by PADI for violations of standards. As can be seen from Figure 1 PADI now trains the majority of new divers.

When analysing accident reports, all events during emergency ascent training were accounted for by the authors. In cases where divers reported symptoms and signs that were indicative of lung over expansion injury, yet were not officially diagnosed as such, we have reported them as embolisms.

During the four year period, approximately 3,754,704 emergency ascents were conducted. A total of 33 incidents or injuries occurred, including two fatalities (one during a buddy breathing ascent and one during a controlled swimming ascent). This means that 3,754,671 emergency ascents were conducted successfully without incident. The incidence of injury was very low being 8.7 incidents per 1,000,000 ascents. The death rate was 0.5 per 1,000,000 ascents. Table 3 shows the incidence of reported injury by emergency ascent method for this period. Table 4 provides information about the incidence of lung damage

PADI's position

Since the 1970s PADI has taken a public stand on the necessity for including properly conducted emergency ascent training in the entry level scuba course. At the same time PADI has demonstrated a record of open-mindedness and diplomacy between all involved communities in public safety issues. We will attempt to convince you of the value and need for emergency ascent training for recreational divers. We believe that emergency ascent training is still an important basic survival skill, equally as important as mask and regulator clearing.

Of absolutely vital importance to all divers is the ability to surface safely when low on or out of air. Diving safety and peace of mind at depth require every diver be trained to handle a loss of air supply safely. It is our opinion that motor skill training and modelling are necessary for divers to handle an emergency ascent comfortably. Emergency ascent techniques allow a properly trained diver to do so if the need arises. We need to train divers to avoid this situation, but they must also be trained to manage it if it occurs. In spite of the controversy surrounding this issue, there are safe, effective methods to train divers in these skills. PADI was encouraged in the mid 1970s to conduct emergency ascent training by such people as the late Dr Charles Brown, past Medical Editor of *Skin Diver* magazine and *NAUI News*, who wrote, "I submit that emergency swimming ascent can be taught as safely as routine ascent, if the student is made to realise that he must neither hold his breath, nor actively empty his lungs."[5] Also Dr Karl Schaefer, Director, BioMedical Sciences Department Naval Submarine Medical Research Lab, wrote "I feel it is essential from a practical and from a psychological point of view that the (scuba) divers know how to make a free ascent." in a letter dated December 12, 1976 to Dennis Graver, then National Training Director of PADI. Dr A.B.Rechnitzer, United States Navy, Office of Oceanography, wrote to PADI, "Open water emergency ascent training is probably the strongest contribution to the confidence of a student diver. Having had several occurrences to personally call on this confidence and mental stability, I strongly recommend that open water emergency ascent training be retained in all diver training curriculum." in a letter dated November 3, 1976. These views and others like them, helped shape the basis and rationale for modern recreational scuba training methods.

PADI and the US based Recreational Scuba Training Council (RSTC), as well as the Australian Scuba Council (ASC), maintain that it is vital to develop student ability to manage an abrupt termination of air supply, affecting buddy or self, so as to return safely to the surface, with or without his buddy's aid. We base this view on training millions of divers over the years, and the conclusion of the NSTC and UMS meetings on this topic. [4,6-8]

Students are taught to monitor their air supply closely to avoid an out-of-air problem, however, if an emergency out-of-air situation was to arise after training, and the data suggests that it does, divers need to be adequately trained to return to the surface safely. Global incidence and accident reports confirm the need still exists.[2,3]

The data on the cost effectiveness of various techniques and training are limited. How many drownings have been averted because the individual had been trained is unknown. This figure will never be known, because one must not only find the number of successful emergency ascents that occur in the real world, but also how many made it home because of training. If all the figures were known, one could make a calculated judgment. From a scientific standpoint, no one has adequately shown if the risk of training is worth the benefit or not. In this paper, we present data to help evaluate this question. From a pragmatic viewpoint, however, diving's improving safety record is partly based on what is included in today's diver training standards.

Why should we conduct emergency ascent training? This has been discussed in the previous paper.[1] We believe that emergency ascent training significantly increases diver confidence and reduces anxiety. Self confidence and psychological mastery can actually prevent panic in an emergency situation. Additionally we should conduct emergency ascent training because these skills work equally well in all geographical areas, and thereby reduce accidents. Finally, we should conduct emergency ascent training because our personal experience and intuition as diving educators tell us we should.

The most easily corrected factor causing diving accidents is running out of air in the first place! This can be to avoided. No one should dive without a tank pressure gauge. Each diver should watch this gauge and plan to arrive at the surface with air in reserve. The need for emergency ascent training would be non-existent if we could guarantee divers would never lack air underwater. Human behaviour being what it is, we know this will never be the case. Without such a guarantee, we have an obligation to provide student divers with safe procedures to save their own lives should the need arise.

It is vital that we train divers in safe, realistic emergency procedures. Emergency ascent exercises are designed so that the students experience that it does work, thus breaking through the psychological barriers of fear and doubt. To do this, training methods need to be simple and effective and carried out under a variety of conditions. The training community has developed procedures that get the student relaxed and confident. Modern emergency ascent training methods are tightly controlled exercises evolved from the cooperative efforts of the educational, scientific and medical community.[1]

After certification, the responsibility for air management lies with the individual diver. The training community faces a responsibility to train the diver with all the skills necessary to dive safely and return to enjoy another dive on another day. Coping with an-out-of air emergency is considered to involve advanced motor skills. Educational experts around the world agree that practice is essential to develop advanced motor skills adequately. On these grounds alone it would seem that emergency ascent training requires not only inclusion in the modern scuba course, but its removal would result in a direct reduction in the quality of the diver produced. Certainly, any diver who did not have the opportunity to practice emergency ascent training under instructor supervision, would have potential difficulties in co-ordinating the actual process under a real emergency.

In our understanding of the problem, we cannot foresee any alternative to emergency ascent training that would be completely satisfactory, if our goal is to eliminate all risks. Any approach to reach a solution will be faced with the knowledge that it will not provide for all eventualities. We are forced to consider trade offs that will, hopefully, put the risk-benefit ratio into an acceptable framework. Accepting or rejecting any course of action in emergency procedures in general should be based upon an objective assessment of risk verses benefit.

Modifying ascents to a horizontal simulation, as some have suggested, has major drawbacks. These methods are low on actual student confidence and psychology building for the real world. Simulations also are only used to a point in other industries. Eventually, one must have the confidence to perform the real skill. Examples include, flying an airplane, submarine escape and abandon ship drill in the Navy. Simulations ultimately are followed by actual practice and experience.

Loss of a diver's air supply may result from several factors, but in most instances it can be traced directly to poor or no dive planning, mismanagement of air supply, or in some instances, equipment malfunction. We believe dive planning relating to air supply should take into account several factors. These include existing water temperature, dive depth, physical activity level, total amount of air available, breathing rate an amount of reserve required for the dive. A submersible pressure gauge is an excellent monitor of air supply, and if used properly, will keep divers from running our of air.

Collective views

There are several notable conclusions found within the proceedings of the Undersea Medical Society Emergency Ascent workshop.[4]

"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." (page 8)

"After further discussion, the group reached the consensus that open water emergency ascent training was not only important, but highly desirable and morally justified." (page 10)

"The requlator should not be removed from the mouth during a swimming ascent, since attempts to inhale through it may help." (page 19)

"Greater standardization of emergency ascent training and equipment was also recommended by the group." (page 21)

The major conclusions of the discussants were (page 21),

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 risks involved,"

3 "every effort should be made by the training agencies to improve training techniques to minimise 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."

4 "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."

The RSTC has put into place an improved medical screening process. Modern emergency ascent procedures and methods have taken into account the technique modifications suggested by the 1977 Workshop to minimise the risks in training.

Conclusion

As major stakeholders in diver safety issues, PADI and SPUMS must work together to develop the very best set of recommendations and methods, based on what we have learned and know today, to provide the millions of recreational scuba divers with the best training possible to manage safely the variables of scuba diving. We greatly value the opportunity to discuss these issues and come to a shared view. The diving public and community at large look to both groups for guidance and leadership.

References:

1 Richardson D. Current philosophy and practice of emergency ascent training for recreational divers. *SPUMS J* 1993; 23 (4): 214-222

2 *1990 Report on Diving Accidents and Fatalities*. Durham, North Carolina: Divers Alert Network, 1992

3 *1991 Report on Diving Accidents and Fatalities*. Durham, North Carolina: Divers Alert Network, 1991

4 Samson RC and Miller JW. *Emergency ascent training. The Fifteenth Undersea Medical Society Workshop* December 10-11, 1977. Bethesda, Maryland: Undersea Medical Society, Inc., 1978: 31-32

5 Brown CV. Emergency ascent training. *Pressure* 1976; 5

6 NAUI, PADI, NASDS, YMCA and SSI. NSTC ascent agreement *NAUI News* 1977; (July/August): 4-5

7 Graver D. NSTC agrees on emergency procedures. *PADI Training Bulletin* 1977; 77-2: 2.

8 Graver D. NSTC Policy On Emergency Procedures. *PADI Training Bulletin* 1977; 77-2: 2-3.

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A MEDICAL VIEW OF EMERGENCY ASCENT TRAINING.

John Knight and Guy Williams

Introduction

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

Why does a diver do an emergency ascent ?

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

What does the diver need from an emergency ascent ?

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

Are emergency ascents always successful ?

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

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

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

Is there much need for emergency ascents ?

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

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

Why practice emergency ascents ?

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

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

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

Is emergency ascent training adequate ?

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

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

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

Certainly no training agency is teaching such a technique.

Against practicing

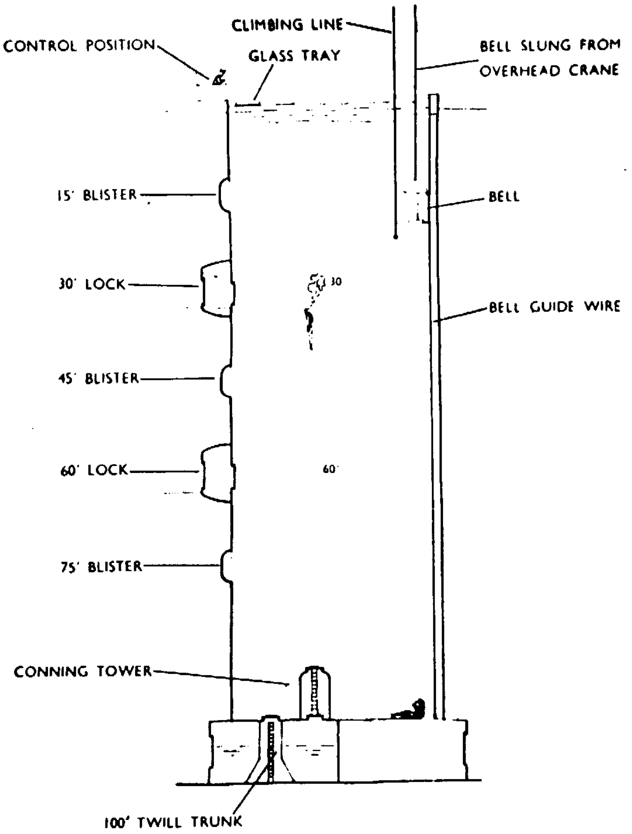
With vertical ascents, such as specified by PADI,[8] the instructor is put through a number of ascents. This has lead to instructors requiring recompression.[9]

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

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

FIGURE 1

DIAGRAM OF 30 M SUBMARINE ESCAPE TRAINING TOWER



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

FIGURE 2

SETT BUOYANT ASCENT

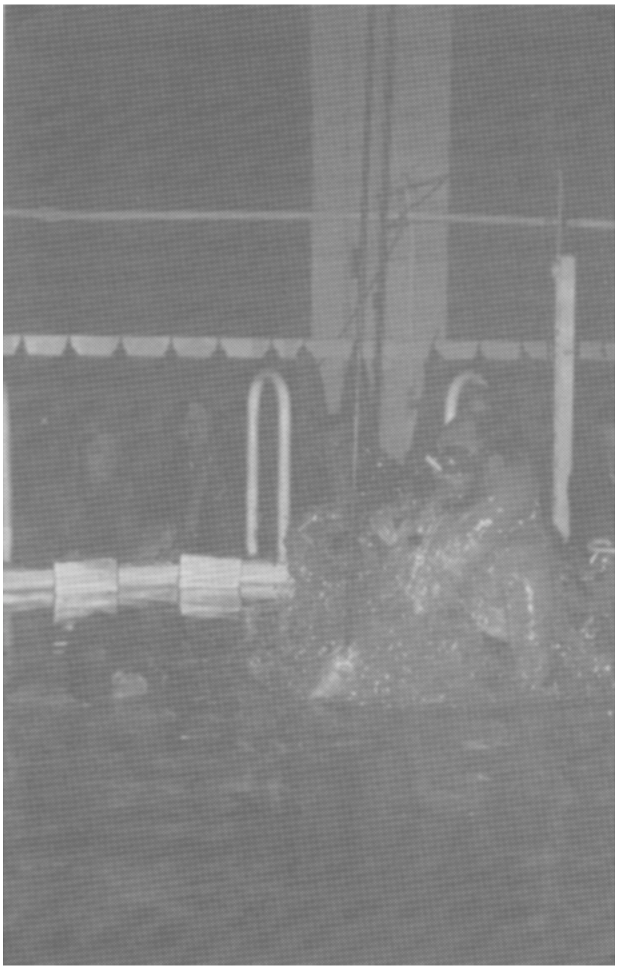


FIGURE 3

SETT ASCENT USING A BUCKET OVER THE HEAD

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

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

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

FIGURE 4

SETT ASCENT WEARING A SURVIAL SUIT

FIGURE 5

SETT TRAINEE IN EXPOSURE SUIT BREAKING THE SURFACE

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

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

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

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

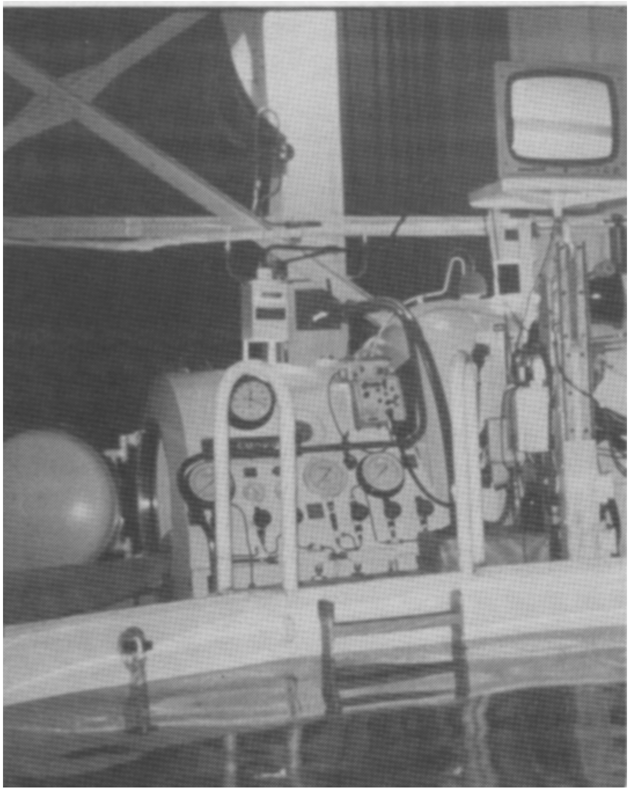
On the other hand not breathing out enough can leave the lung over-inflated, again predisposing to lung damage on ascent.

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

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

FIGURE 6

RECOMPRESSION CHAMBER AT TOP LEVEL OF SETT



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

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

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

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

What is needed for a safe emergency ascent ?

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

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

TABLE 1

FOR A SAFE EMERGENCY ASCENT

Head for the surface as soon as the problem starts

Use a procedure which will
- **guarantee the diver reaching the surface,**
- **reduce the risk of hypoxia on the way up,**
- **is easy to remember,**
- **and has been practiced many times.**

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

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

Is such a procedure possible ?

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

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

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

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

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

TABLE 2

TO ACHIEVE A SAFE EMERGENCY ASCENT

Waste no time in becoming buoyant

Keep the regulator in

Attempt to breathe in and out all the way up

Undo the weight belt and hold it away from the body

What needs to be taught ?

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

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

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

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

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

Conclusions

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

Some emergency ascent training is dangerous to pupil or instructor.

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

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

References

1 Edmonds C and Walker D. Scuba diving fatalities in Australia and New Zealand 1 The human factor. *SPUMS J* 1989; 19 (3): 94-104
2 Edmonds C and Walker D. Scuba diving fatalities in Australia and New Zealand 3 The equipment factor. *SPUMS J* 1991; 21 (1): 2-4
3 Halstead Bob. How experienced divers really dive. *SPUMS J* 1992; 22 (3): 171-174
4 Egstrom G. Diving fitness. *SPUMS J* 1992; 22 (2): 98-102
5 *Emergency ascent training. 15th Undersea Medical Society workshop*. Ed Kent MB Bethesda, Maryland; UMS, 1979
6 Walker D. Scuba training for the out of air situation *SPUMS J* 1990; 20 (1): 7-19
7 Nemiroff MJ. In *Emergency ascent training. 15th Undersea Medical Society workshop*. Ed Kent MB Bethesda, Maryland; UMS, 1979:10
8 Myers J. The ups and downs if controlled emergency swimming ascent training. *The Undersea J* 1992; 4th quarter: 90-91
9 Walker R. 50 divers with dysbaric illness seen at Townsville General Hospital during 1990. *SPUMS J* 1992; 22 (2): 66-70
10 Campbell EJM, Martin HB and Riley RL. Mechanisms of airway obstruction. *Bull Johns Hopkins Hosp* 1957; 101: 329-343
11 Harpur GAD and Suke R. Hypoxia in out-of-air ascents, a preliminary report. *SPUMS J* 1984; 14 (4): 24-28 (reprinted on pages 205-210 of this issue)
12 Wong TM. Buoyancy and unnecessary diving deaths. *SPUMS J* 1989; 19 (1): 12-17
13 Edmonds C, Loxton M, Pennefather J and Strack C. Deep diving and some equipment limitations. *SPUMS J* 1992; 22 (1): 20-24
14 Harpur G. First aid priorities for divers; The Tobermory viewpoint. *SPUMS J* 1982; 12 (4): 32-38 (Reprinted on pages 198-205 of this issue)

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

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

THE SPUMS WORKSHOP ON EMERGENCY ASCENT TRAINING

Des Gorman and Drew Richardson
Workshop Co-Chairmen

Introduction

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

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

a to develop (if possible) a SPUMS policy on EAT; and,
b to illustrate that a Workshop is an appropriate method of forming Society policy.

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

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

The workshop

A series of fundamental questions was addressed and both the key-note addresses and the subsequent discussion are summarised below.

Is there a need for emergency ascent training?

This question was largely answered by Chris Acott in his presentation, from the Diving Incident Monitoring Study (DIMS), of those incidents of being out-of-air/low on air (pages 222-225).[2] Approximately 20% of more than 500 incidents reported to DIMS have involved such a situation, many leading to an emergency ascent. Those involving buddy breathing often caused later problems (salt water aspiration). The utility of alternative air supplies (e.g. SPARE AIR) was discussed. Chris Acott reported that a fully pressurised SPARE AIR cylinder provided about 20 breaths at 20 msw, but that mechanical problems with the regulator system had been experienced. Guy Williams confirmed this experience. It was agreed that while the availability of alternative air supplies may reduce the frequency of needing to perform an emergency ascent, it would not reduce the need for training in emergency ascent techniques. Considerable support existed for the reintroduction of sonic reserves. Complete redundancy of equipment (e.g. cave diver's rig) was not considered necessary in conventional recreational diving.

The following conclusions were drawn from Chris' presentation and the ensuing discussion:

a despite the current emphasis in training on attention to air supply status, recreational divers still occasionally exhaust their air supplies;
b inflation of a buoyancy vest can rapidly convert a low on air to an out-of-air situation;
c dependent ascents (buddy breathing and octopus assisted) are often impossible because of the separation of diving buddies; and,
d buddy breathing under stress often causes salt water aspiration in both participants.

How do the recreational instructor groups train entry level SCUBA divers in emergency ascents?

Drew Richardson presented an overview of NAUI, PADI and SSI training techniques (pages 214-222).[3] Drew divided techniques into dependent (assisted) and independent groups. During the discussion, Phil Bryson and Bob Borer described how these techniques differed from those employed by the British Sub-Aqua Club (BS-AC). The lack of a centrally accepted and applied training standard made consideration of CMAS policies impossible.

It was evident that the great majority of trainees are neither taught nor practise a true free ascent. A "free ascent" is defined here as an ascent that requires no equipment, in which the subject exhales into the water, and where the ascent is controlled by respiratory volume alone. The emergency swimming emergency ascents in training are performed with a regulator kept in the mouth. This latter practice was strongly advocated in the subsequent presentation by Guy Williams on behalf of John Knight (pages230-236).[4]

What is the efficacy and risks of emergency ascent training?

None of the Workshop presentations included data on the efficacy of EAT, with the exception of Chris Acott's DIMS data which suggested a significant morbidity for buddy breathing ascents (pages 222-225).[2] However, John Williamson argued strongly that data from resuscitation training show that even a single trial of, or exposure, to a technique significantly improves performance of that technique in an emergency. It is likely that Chris Acott's continuing DIMS study will provide considerable insight into the efficacy of EAT.

Guy Williams read a paper from John Knight outlining the health risks of EAT to both the trainees and their instructors (pages 230-236).[4]

John Knight considered the major risks to the trainees to be:

a pulmonary barotrauma;[5]
b salt water aspiration;[2] and,
c hypoxia.[6]

Using submarine escape training tower (SETT) data, John Knight estimated that the risk for each emergency-ascent-exercise was about 1:2,000 for pulmonary barotrauma (including air embolism) and about 1:40,000 for sudden death. These data contrast sharply with those presented subsequently (pages 225-230).[7]

The critical data that enabled an overall consensus to be reached were presented by Terry Cummins on behalf of himself and Drew Richardson (pages 225-230).[7] Based on PADI training records and PADI accident reports (likely to be inclusive due to the link between reports and liability insurance), the following data were presented:

a PADI have records of more than 3,754,704 trainee EAT vertical ascents to the surface in open water;
b the associated injury rate is about 1:100,000 ascents for trainees; and,
c the associated fatality rate is about 1:2,000,000 ascents for trainees.

The size of the denominator encourages confidence in these figures. Consequently, it is evident that EAT is a negligible risk to trainees and, as conducted by PADI, is at least 50 times safer than SET.[4] Many of the conventional "medical" objections to EAT have been based on SETT figures, for very fast ascents, which were, until the Cummins and Richardson paper, the only available statistics. Many participants were influenced to modify their stance by this PADI data.

The production of the PADI data at a SPUMS meeting is a significant demonstration of the maturing relationship between SPUMS and the recreational diving industry. In previous years, such data would not have been shared with SPUMS for fear of its "mis-use".

John Knight also used the experimental data of Harpur and Suke[6] from Tobermory, Canada, to argue that hypoxia was a major cause of a loss of consciousness during an emergency ascent and to advocate the emergency ascent technique proposed by Harpur at the 1977 UMS Workshop on EAT.[1,4,6]

It was agreed by the SPUMS Workshop, notwithstanding that the Harpur and Suke[6] trial involved divers ascending from a ventilatory starting point of functional residual capacity (FRC), that hypoxia was a major problem in emergency ascents and would be exaggerated by work performed in trying to contact a separated buddy. It was also and consequently agreed that:

a the fundamental nature of the technique advocated by Harpur[1] and those taught by NAUI (emergency swimming ascent), PADI (controlled emergency swimming ascent) and SSI (emergency swimming ascent) is common;

b EAT simulation by horizontal swimming does not provide realistic practice for either breath or buoyancy control;

c. the technique of not ascending completely to the surface (recommended by Professor Elliott) should be safer (by avoiding the greatest dysbaric stress) but would not be as effective a training activity;

d other than trainees repeatedly practising to remove their weight belt effectively, without actually ascending, there was little to be gained by actually conducting a buoyant ascent over and above the controlled swimming ascents;

e the use of a vertical ascent line improved the safety of all techniques; and,

f time and already depleted gas supplies should not be exhausted trying to re-establish contact with a significantly separated buddy, and an early decision to ascend to the surface should be encouraged.

A consensus could not be reached on buddy breathing. Many of those at the Workshop argued that the practice was dangerous and some anecdotes suggested that it may be lethal. Greg Leslie, with an apt fornication-based analogy, suggested that buddy breathing should be restricted to established "buddy-pairs". It was however agreed that, if Chris Acott's DIMS Study (pages 222-225)[2] continues to demonstrate a significant morbidity for buddy breathing, that it should be actively discouraged.

The risks of EAT to the Instructor, multiple ascents and a consequent risk of decompression illness (DCI), were then debated. Although such instructors were grossly over-represented in a series of divers treated for DCI at Townsville,[8] other centres have not reported such a bias.[9] It was nevertheless agreed that the number of ascents performed by an instructor during a dive with trainees should be minimised (but not to any arbitrary level such as 5 ascents/dive as imposed in some training facilities in the United Kingdom).

The SPUMS policy developed at this Workshop is printed on page 239.

References

1 Samson RC and Miller JW. *Emergency ascent training*. The fifteenth UMS Workshop. Bethesda, Maryland: UMS, 1977.

2 Acott C. Out-of-air ascents from the Diving Incident Monitoring Study *SPUMS J* 1993; 23: 222-225

3 Richardson, D. Current philosophy and practice of emergency ascent training for recreational divers. *SPUMS J* 1993; 23: 214-222

4 Knight J and Williams G. A medical view of emergency ascent training. *SPUMS J* 1993; 23: 230-236

5 Francis TJR and Gorman DF. Pathogenesis of the decompression disorders. In: Bennett PB, Elliott DH, Eds. *The physiology and medicine of diving. 4th ed*. London: W.B. Saunders, 454-480

6 Harpur GAD and Suke R. Hypoxia in out-of-air ascents. A preliminary report. *SPUMS J* 1984; 14(4): 24-28, reprinted SPUMS J 1993; 23 (4): 205-210

7 Richardson D and Cummins T. A training agency perspective of emergency ascent training. *SPUMS J* 1993; 23: 225-230

8 Fallowfield T. Management of diving related illnesses in Townsville. *SPUMS J* 1993; 23(1): 30-33

9 Gorman DF and Harden M. Studies of outcome after treatment for decompression illness in Australasia. *SPUMS J* 1993; 23: 165-168

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SPUMS POLICY ON EMERGENCY ASCENT TRAINING

The SPUMS policy on EAT developed at the 1993 Workshop is summarised below.

1 The frequency of recreational divers becoming low on air or running out of air completely is unacceptably high. Instructor agencies must increase the training emphasis on attention to air supplies and to avoiding unnecessary inflation of buoyancy vests, especially when air supplies are low. The latter will also require an improvement in buoyancy control. The availability of alternative air supplies does not obviate the need for avoiding low on air and out-of-air situations. A sonic reserve alarm may be helpful.

2 An alternative (i.e. independent; e.g. SPARE AIR or redundant scuba cylinder) supply of air is recommended for deep diving (beyond 30 m), cave diving, penetration wreck diving, staged decompression diving and other diving where entanglement is likely. The alternative supply must be appropriate to the circumstance.

3 Emergency ascent training should be taught to and practised by entry level scuba trainees.

a ***Academic information only.*** Positive buoyant ascent (when the diver drops his or her weights and utilises lift from all forms of buoyancy, BCD and exposure suit).[1]

b ***Academic information and confined water (eg pool or lagoon) skills training.*** Weight-belt removal and buddy breathing, when two or more divers share a common air supply by passing the regulator second stage from one diver to another.[1]

c ***Academic information, confined and open water skills training.*** Emergency (controlled) swimming ascent (when the diver swims to the surface with the regulator in the mouth, exhaling continuously), octopus assisted ascents (using an alternative air source, usually an additional second stage known as an octopus regulator) and normal ascents (a direct swimming ascent, with the mouth-piece in place).[1]

4 Emergency ascent training to the surface should be confined to a maximum depth of 9 m.

5 Emergency ascent training should be conducted vertically and involve a vertical safety-line.

6 The number of students per instructor, the number of assistant instructors and the conduct of EAT should be organised to minimise the number of ascents that instructors and their assistants have to perform.

7 The safety and efficacy of buddy breathing is suspect and is under active review.

Reference

1 Richardson D. Current philosophy and practice for emergency ascent training for recreational divers. *SPUMS J* 1993; 23 (4):214-222

SPUMS ANNUAL SCIENTIFIC CONFERENCE 1993

DIVING MEDICINE IN MICRONESIA 1991 - 1993

Alise Curry

Abstract

Micronesia is a vast remote area of the Pacific containing several premier diving sites. A review of 68 recompression treatments, for 52 patients, performed from January 1991 to March 1993 at the US Navy's facility on Guam showed that 50 (96%) of the diving accidents occurred in recreational divers, 31 (60%) of whom were civilians. Forty seven cases (90%) involved decompression illnesses (DCI). Type I decompression sickness (DCS) was diagnosed in 10 (19% of the total), DCS Type II in 27 (52%), cerebral arterial gas embolism (CAGE) in 10 (19%) and retrospective diagnoses of musculoskeletal pain in 3 (6%), marine animal sting in one (2%,) and conversion disorder in one patient. All but 3 patients completely recovered using standard US Navy (USN) Treatment Tables. Forty-eight percent of patients' dives clearly exceeded USN decompression tables, 13% ascended rapidly, 4% ran out of air, 4% flew soon after diving, and one had been an inside tender on a preceding treatment. However 25% had no apparent cause of their accident. Seventy-three percent of the accidents occurred on Guam (by far the most frequently dived spot); a relatively high rate of accidents on Truk is attributed to poor planning at deep dive sites. In the future, recompression facilities are planned at remote dive sites. Meanwhile, improved diving safety practices are imperative.

Diving Medicine in Micronesia

Micronesia consists of several thousand small islands scattered over an 11,000,000 square kilometre area of the north central Pacific. The climate is tropical and the area includes some of the world's premier diving locations. The isolation of the developing nations in the area presents some unique problems in diving medicine.

The economic centre of Micronesia is the US territory of Guam. The military maintains a strong presence on Guam in the form of a Naval Station, two Air Stations, a Communications Master Station and a Naval Hospital. Two recompression chambers are maintained locally by USN divers. These chambers are primarily intended for use by military divers; however, virtually all treatments are conducted for recreational divers, most of whom are civilian.

This paper will review the 68 recompression treatments performed from January 1991 to March 1993. Characteristics of the patients and the circumstances surrounding their injuries will reveal trends that may be of use to other treatment facilities which primarily serve a recreational diving population.

Recompression Facilities in Micronesia

The US Navy's chambers are located at the Naval Station and on board USS Holland (a submarine tender). For practicality, the Naval Station chamber is most often used for treatments. It is a double lock chamber in use since the 1960s. It does not have environmental control or life support equipment. It has a built in breathing system (BIBS) for oxygen and a simple ventilation system. A diver is on duty 24 hours a day. Both the military and civilian medical systems are well aware of the facility and most local patient transfers occur in a timely manner. Transfers from off-island are coordinated by the US Coast Guard and may utilise Navy H46 helicopters or P3 multi-engine aircraft as needed.

The only other consistently operable recompression chamber in Micronesia is in Palau. It is a single-lock monoplace chamber and is located in the local hospital. Most practitioners are US Public Health physicians and have acquired some diving medicine training through the Divers Alert Network or the US Navy. In the event of a diving accident, they contact the Navy facility in Guam and a decision is made to treat in Palau or to transfer to Guam. During the study period, two table 6 treatments were performed in Palau with good results.

Truk Atoll has a double lock recompression chamber which was donated by the United States in the late 1980's. It is intended also for use for victims from Pohnpei, which lies 600 km east of Truk. Unfortunately, scarce financial resources, constantly fluctuating medical personnel and poor maintenance have combined to render the chamber unusable since early 1991. Therefore, all accident victims must be flown for three to five hours to Guam, often after treatment delays.

Other popular dive locations lie in the Northern Mariana Islands, just north of Guam. As the capital, Saipan, is only 200 km away, military medevacs to Guam are usually expeditious.

Patient Demographics

A total of 52 patients were treated during the study period. Seventy-three percent were male, 27% female. Age distributions and nationalities are shown in Tables 1 and 2. It is interesting to note that although the 7 Japanese tourists made up only 13% of accidents victims, they sus-

TABLE 1

AGES OF PATIENTS

Age	Number	%
Under 30	3	6
31-40	24	46
41-50	17	32
51-60	1	2
61 and over	3	6
Unknown	4	8
Total	**52**	**100**

TABLE 2

PATIENT DEMOGRAPHICS

Nationality	Number	%
Local Caucasians	30	57
Japanese	7	13
Micronesian	5	10
American tourists	3	6
Military	2	4
Australian	2	4
European	2	4
Filipino	1	2
Total	**52**	**100**

tained three (30%) of the cerebral arterial gas emboli. Additionally, all Japanese tourist CAGEs were sustained at the same dive site, at which divers are required to descend to at least 39 m (130 ft). It may be postulated that these divers were relatively inexperienced and were taken to advanced dive sites without proper qualification. It may surprise some that relatively few accidents occurred among the local population. There is a strong cultural aversion to ocean swimming among Micronesians. Few become qualified divers and there is very little commercial diving. Only two treatments were performed for military working divers; one of these was for a diver who developed symptoms of DCI after serving as inside tender for a USN table 6, and the other was for minor Type II DCS symptoms. Sixteen cases (30%) occurred in individuals who would normally be eligible for military medical care (active duty working and recreational divers, allied military members, military dependents and retirees).

Only two CAGEs occurred in Open Water Dive classes. Considering that approximately 1,000 divers are trained each year on Guam, this would appear to be an acceptable figure. Interestingly, however, five DCI cases occurred among scuba instructors. Only one was associated with classes. The other four happened during dives which clearly exceeded USN tables.

Recompression Facility Use 1991-1993

During the study period, a total of 68 treatments were conducted by the US Navy's facility (Table 3).

TABLE 3

DIAGNOSES

Diagnosis		Number		%
Decompression illness		47		90
Type 1	10		21%	
Type 2	27		58%	
CAGE	10		21%	
Conversion disorder		1		2
Marine sting		1		2
Muscle pain		3		6
Total		**52**		**100**

The final diagnoses were DCI in 47 cases (90%). This was made up of 10 (21%)Type I DCS, 27 (58%) Type II DCS and 10 (21%) CAGE. The other cases were 3 (6%) with musculoskeletal pain, and one (2%) marine animal sting. The final patient was treated on lengthy tables, twice, for what eventually appeared to be a conversion disorder. This interesting patient was a 34 year old female with an underlying eating disorder and a history of intravenous drug abuse. She admitted to being both highly apprehensive of and very keen to participate in recreational diving. On both occasions, she apparently became unconscious underwater (but never lost her regulator nor lost control of her ascent). Since she was unresponsive when brought to the chamber, she was assumed to have embolised and was treated accordingly. An alternating pattern of delirium with combativeness, right sided hemiplegia, and lucidity with a normal neurological examination developed after several hours in the chamber. This unphysiological pattern of injury and a later diagnosis of borderline personality disorder suggested the diagnosis.

TABLE 4

TREATMENT TABLES USED

USN Table	Number	%
6	54	79.0
6A	8	12.0
7	4	6.0
4	1	1.5
8	1	1.5
Total	**68**	**100**

Most patients responded to a USN Treatment Table (table) 6 (Table 4). Eight of ten CAGE patients were treated with a table 6A, while 2 CAGE patients shared the chamber for a table 7. Two dive buddies required a table 7 for DCI after performing a dive to 54 m (180 ft) for 30 minutes. They both surfaced with lower extremity paraesthesiae and attempted to recompress themselves in the water for 120 minutes using a table of their own devising. During this their symptoms worsened considerably. The conversion disorder patient was treated on a modified table 8 and a table 4 for her two separate incidents. Nine patients required from one to ten subsequent retreatments, all utilising a table 6.

Only three patients had significant residual neurological deficits, consisting of lower extremity weakness and bladder dysfunction. All had sustained serious initial injuries. One had surface rapidly from over 60 m (200 ft) after her regulator malfunctioned. Another had done multiple dives to more than 30 m (100 ft) in Truk and had approximately a 24 hour delay from accident to treatment. This patient, who was paraplegic when he arrived for treatment, was one of two buddies who carried out self treatment by in-water recompression. The other buddy only had mild joint pains at presentation and recovered fully.

The geographical locations of accident occurrences are shown on Table 5. The relative frequency of accidents on Truk compared to other outlying islands deserves some mention. Truk is renowned for its wreck diving; sixty Japanese vessels were sunk in the atoll by American aircraft in February, 1944. Many wrecks lie in water deeper than 30 m (100 ft). Tourists typically perform multiple deep dives over several days while vacationing in Truk. Dive profile supervision by dive operators is minimal. Five of the seven accident victims were diving with dive computers allowing profiles which grossly exceeded both US Navy and PADI tables. It is disturbing that more care is not taken in dive planning in such a remote location with no local treatment facility.

TABLE 5

ACCIDENTS BY LOCATION

Location	**Number**	**%**
Guam	39	75
Truk	7	13
Saipan	2	4
Tinian	2	4
Palau	1	2
Pohnpei	1	2
Total	**52**	**100**

TABLE 6

CAUSES OF ACCIDENTS

	Number	**%**
Outside tables	25	48.0
DCI within tables	10	19.2
Panic Ascent	7	13.5
AGE unknown cause	5	9.6
Out of air	2	3.9
Flew after diving	2	3.9
Chamber attendant	1	1.9
Total	**52**	**100**

Cause of Accidents

Table 6 shows apparent causes of the diving accidents. Patients' dive profiles were compared to standard US Navy Air Diving Tables (which are less conservative than the recreational tables published by PADI) and considered to involve omitted decompression if they exceeded the Navy Tables for greater than 5 minutes. Almost half of the DCI patients fell into this category. Although reliable statistics were not kept, many were diving with computers; many of these did not plan their dives but relied upon their computers to “plan for them”. However 10 divers (19% of the DCI patients) utilised conservative profiles. Interestingly, all were healthy non-obese individuals less than thirty years of age and would traditionally be considered low risk; half were male and half were female. Additionally, one-third of CAGE patients were not known to have ascended rapidly and had no known underlying medical problems.

It also deserves mention that two individuals were bent upon a return air trip from the island of Rota, which lies only 66 km north of Guam. They had performed a conservative 15 m (50 ft) dive six hours before boarding a small unpressurised plane to Guam. Both began to experience upper extremity parenthesise at altitude. They both recovered quickly during a Treatment Table 6.

The Future of Diving Medicine in Micronesia

The establishment of reliable civilian recompression facilities in Micronesia is an ultimate goal. Local governments are very interested in supporting the tourism industry with any needed emergency medial care. Additionally, the USN would eventually prefer to reserve their facility for their own beneficiaries and allow working divers to be more available to support fleet needs. The governments of Guam and Saipan are currently actively working to establish facilities; these cannot realistically be expected to be operational for at least three years. Palau is also working to replace their current chamber with a double-lock multiplace chamber. The situation in Truk is obviously a pressing problem. The US Government has offered assistance to the Trukese in the form of regular chamber maintenance by Navy divers and education of local practitioners in diving medicine. Local diving operators have also been approached for assistance in manning the recompression chamber. Hopefully, the newly elected government in Truk will accept this assistance and the facility will again be operational soon.

The Naval Station has received funding to modernise their chamber with a environmental package including a air sampler, a CO_2 scrubber, an air chiller and an updated oxygen delivery system.

Meanwhile, accident prevention is continuously stressed. The largest diving organisation in Guam now only allows advanced divers on their sponsored deep dive trips. Local instructors are increasingly stressing the importance of dive planning in their courses. The emergency contact numbers for the recompression facility are widely distributed at diving facilities and is contained in the emergency section of all local telephone books.

Improved diving safety is imperative on remote islands. Tourists must be aware that scarce health care funds are spent preferentially on basic care of the native population rather than on a complex piece of equipment which may only occasionally be used. As can be seen in the preceding discussion, some accidents will invariably occur despite proper procedures. Many accidents are preventable however, and divers should take special precautions in isolated areas where prompt help may not be available.

Lieutenant Alise Curry served as Diving Medical Officer for US Naval Hospital Guam for the two years covered in this study.

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ROYAL AUSTRALIAN NAVY SCHOOL OF UNDERWATER MEDICINE DIVING MEDICINE COURSE 1994

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FITNESS TO DIVE MEDICAL STANDARDS
8th-11th March 1994, Edinburgh Conference Centre
Heriot-Watt University, Scotland

Many standards exist for determining the medical fitness of divers. These criteria differ according to the category of diving to be performed, and they also differ from country to country. Many doctors experience difficulties when applying these fitness guidelines to some individuals. Improved clarity and harmonisation is needed.

This meeting will provide diving doctors with an opportunity to present selected difficult or borderline cases for discussion with consultants, may of whom have been advisers on cases in which divers have appealed against disqualification.

Another purpose of this conference is to review fitness standards on the basis of experience, and to seek a firm basis for international agreement. Though primarily for the sixteen nations of the European Diving Technology Committee, the proposed standards will be important to divers worldwide. The scope is intended to cover all working diver, i.e. offshore, inshore and inland. This includes police, scientific divers and sports-diving instructors. Fitness for sports diving will be reviewed, not for standard setting, but as a source of much valuable experience. (See back page for details)

The conference will also consider the standards for recording, at each periodic examination, the medical data needed for long term health surveillance and epidemiology. It will assess the need for a registry, which includes exposure data, to facilitate the recognition of diving-related illnesses and to recommend preventive measures.

Delegates will assemble in Edinburgh on the evening of Monday 7th march and the following four days will be devoted to diver fitness in relation to in-water safety and long-term health. The topics will include the specific medical and physical standards for each organ-system, the training of examiners, the special facilities and equipment required, record keeping and the role of data banks for health surveillance. High-lighted features will include ageing, exercise tolerance tests, PFO's, hearing loss, pulmonary function testing, special neurological investigations, long-term sequelae, and the return to diving after illness, accident, surgery or decompression incident.

Registration Fees

Full 4 day conference (includes banquet)	£315.00
Daily registration	£127.00
Banquet	£35.00

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