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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.

MEMBERSHIP

Membership is open to medical practitioners and those engaged in research in underwater medicine and related subjects. Associate membership is open to all those, who are not medical practitioners, who are interested in the aims of the society.

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INSTRUCTIONS TO AUTHORS

The SPUMS Journal welcomes contributions (including letters to the Editor) on all aspects of diving and of hyperbaric medicine. Manuscripts must be offered exclusively to the SPUMS Journal, unless clearly authenticated copyright exemption accompanies the manuscript.

Minimum Requirements for Manuscripts

All contributions should be typed, double-spaced, using both upper and lower case, on one side of the paper only, on A4 paper with 45 mm left hand margins. All pages should be numbered. No part of the text should be underlined. These requirements also apply to the abstract, references, and legends to figures. Measurements are to be in SI units (mm Hg are acceptable for blood pressure measurements) and normal ranges should be included. All tables should be typed, double spaced, and on separate sheets of paper. No vertical or horizontal rules are to be used. All figures must be professionally drawn. Freehand lettering is unacceptable. Photographs should be glossy black-and-white. Colour prints or slides will normally be printed as black and white. Colour reproduction is available only when it is essential for clinical purposes and may be at the authors' expense. Legends should be less than 40 words, and indicate magnification. Two (2) copies of all text, tables and illustrations are required.

Abbreviations do not mean the same to all readers. To avoid confusion they should only be used after they have appeared in brackets after the complete expression, e.g. decompression illness (DCI), and thereafter czn be referred to as DCI.

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

Computer compatibility

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Consent

Any report of experimental investigation on human subjects must contain evidence of informed consent by the subjects and of approval by the relevant institutional ethical committee.

Editing

All manuscripts will be subject to peer review, with feedback to the authors. Accepted contributions will be subject to editing.

Reprints

The Journal does not provide reprints.

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SPUMS ANNUAL SCIENTIFIC MEETING 1991

SPUMS ANNUAL SCIENTIFIC MEETING 1992

REPORTS OF OTHER DIVING AND HYPERBARIC MEETINGS

GLEANINGS FROM MEDICAL JOURNALS

Abstracts from the Undersea and Hyperbaric Medical Society Annual Scientific Meeting 1992

MEETINGS AND COURSES

THE MARINE STINGER HOTLINE
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For advice about the treatment of marine stinger injuries dial **008-079-909**.

DIVER EMERGENCY SERVICE
008-088-200

The DES number 008-088-200 can only be used in Australia.
For access to the same service from outside Australia ring ISD 61-8-223-2855.

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

This issue has more letters about what the SPUMS Journal should be. These are firmly on the side of being an independent medical journal. We have always attempted to be this.

The Journal contains original articles, which are peer reviewed, and should not have appeared in any other journal. There have been some recent breaches of this rule, because authors did not mention that the papers had been published before. An important part of the Journal is the section of SPUMS Notices. By publishing the minutes of Executive Committee meetings we keep all readers up to date with the running of the Society. The presentations at Annual Scientific Meetings (ASMs) are also printed so that all members can benefit from them. These are expected to be original contributions or, at the worst, new versions of previously published information This means that the texts supplied by some guest speakers have to be reworked into new presentations. This is done if the supplied text has obviously been published before. Sending photocopies of previous publications or texts headed "Presented at" is an obvious giveaway. As an educational service we reprint articles of interest from other journals, with permission from, and acknowledgement of, the original source. Finally there is a selection of abstracts reprinted, with permission and acknowledgement, from other journals. This is an attempt to help members keep up to date with underwater and hyperbaric medicine.

Problems have arisen from the publication of ASM papers. Probably from lack of knowledge of our no-censorship policy people have assumed that these presentations have been "officially approved". This is a misapprehension. SPUMS, like all medical societies, encourages new information and discussion, and if necessary disagreement, at its meetings. The situation has been exacerbated by some non-medical people claiming that presentation at a SPUMS ASM is an "official SPUMS endorsement" of the views expressed there. Again one assumes that such people did not know of the no-censorship policy. One should always read the cover page and remember the disclaimer at the bottom.

We have found that some original papers are not truly scientific but well worth publishing. So this issue sees the start of a new section. In THE WORLD AS IT IS we will publish peer reviewed papers of interest to divers. We start with a paper about the odd attitude of the Australian Medical Association (AMA) to diving medicals. The article ends with a plea to members and associates to write to the AMA supporting the SPUMS stance that diving medicals should only be done by those who have the appropriate training. We hope that many readers will inform the AMA of our views and influence them to change their tack. The other paper discusses the numbers and costs of resort courses in Queensland. There is no doubt that this is big business.

Readers may be surprised to find a book review reprinted from the British Medical Journal (BMJ). It is there because the Editor dislikes having to rewrite papers submitted for publication. While it is rewarding to have an author write that his work has been much improved by editing, the process takes much time and effort. Intending authors are encouraged to use their Mastercard, Visa or American Express card to purchase "Medical writing: a prescription for clarity".

Chris Acott's paper on diving incidents shows once again that drugs and alcohol are incompatible with safe diving. An incident due to incompetence with the diving tables or being medically unfit to dive is associated with a high chance of damage to the diver.

Glen Egstrom's paper on emergency air sharing is of great interest. The Editor would not like to be offered a device attached to the donor's power inflator to breathe from for fear of interfering with the donor's buoyancy control. That is a personal opinion. Andy Veale's paper on respiratory function in intending divers is informative and timely. Unfortunately it is unlikely that any medical ethical committee would be willing to sanction a controlled trial of diving for asthmatics. So we will never know how dangerous asthma makes diving. But asthmatics have figured in the diving deaths and at least three unpublished cases of unconsciousness underwater in asthmatic trainee divers have occurred in the Melbourne area in the past 15 years. There two abstracts dealing with divers and asthma printed in GLEANINGS FROM MEDICAL JOURNALS.

The two papers from the 1992 ASM cover diving safety and diver rescue. The latter is factual while the first in the Editor's personal views on how to improve diving safety, compressed into a 12 minute presentation. There should be a scope for readers to write many letters to the Editor putting forward their views on what should (or perhaps should not) have been included.

We are pleased to print a report of the first Annual Scientific Meeting of the recently formed Hyperbaric Technicians and Nurses Association (HTNA). They and the ANZHMG will be having a diving and hyperbaric medicine meeting in Darwin next year. A call for papers appears in this issue. We wish both organisations much success.

With this issue comes a list of SPUMS members, in Australia and New Zealand, who have the proper training to do diving medicals and where to find them. It is incomplete as much of the information provided by members was incomplete and so those names do not appear. The back page is for letting the Secretary of SPUMS know you want to be on the list.

Some facts about SPUMS

It has become abundantly clear that many people have odd ideas about what SPUMS (the South Pacific Underwater Medicine Society) is. This editorial was approved by the SPUMS Executive Committee at its last meeting.

To help clear up the current confusion we detail a few facts.

WHAT SPUMS IS

SPUMS is an association of doctors. The Society is run by a committee of doctors. Non-doctors who are engaged in full time diving medical research are also eligible for membership.

Only the Executive Committee can make SPUMS' policy. The President and the Secretary are the two official spokesmen for the Society. No one else can speak for SPUMS unless authorised to do so on some special topic, like this editorial. *The Editors Offering* appearing at the begining of every Journal is to be read as the Editor's views and not an official expression of SPUMS' policies.

The objects of the Society are 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 (the SPUMS Journal) and to convene members of the Society annually at a scientific conference.

Because people other than doctors are interested in underwater and hyperbaric medicine non-medical people can join the Society as associate (non-voting) members. Organisations which earn income by providing services to divers, libraries and government bodies can join as a subgroup of associate members paying a higher subscription (corporate members). The SPUMS Journal is sent to all members and associates four times a year.

SPUMS provides free advice to those who request it. SPUMS represents diving medicine on two Committees of Standards Australia.

SPUMS awards a Diploma in Diving and Hyperbaric Medicine. Candidates must have proper training and experience and provide a thesis. These are assessed by the Board of Censors who also approve, as adequate training, diving medicine courses.

WHAT DES IS

The Diver Emergency Service is a voluntary service, for all divers, provided by hyperbaric medicine experts based at the Royal Adelaide Hospital. It provides free telephone advice, on 008 088 200, twenty four hours a day.

It is a direct descendant of the unofficial 24 hour service started by Dr Carl Edmonds at the Royal Australian Navy School of Underwater Medicine, using the RAN Diving School watchkeepers to pass on messages to the duty doctor.

DES exists because Dr Des Gorman and others were able to persuade the late John Friedrich, of the National Safety Council of Australia (Victorian Division), to fund it as a community service. Since the collapse of the National Safety Council of Australia (Victorian Division) funding the non-medical costs of the service, telephone and secretarial, has been a problem. The part-funding provided by the Commonwealth Government has now been withdrawn.

Treatment of injured divers is not a function of DES. It is the function of the individual hyperbaric units to which divers are referred. One of these units is at the Royal Adelaide Hospital. It is the individual hyperbaric units which provide DES with treatment statistics.

The Diver Incident Monitoring Study is conducted by Dr Chris Acott of the Royal Adelaide Hospital.

WHAT SPUMS IS NOT

SPUMS has no link with DES except to provide money to help keep it in existence. The fact that the doctors who run DES and provide advice free to divers are members of SPUMS does not make DES a SPUMS body.

SPUMS is not part of the “diving industry” except that its members buy diving gear and make use of commercial diving boats in exactly the same way that all divers do.

The only links SPUMS has with diver training organisations are that some of these organisations are corporate members and many diving instructors are associate members. Neither group have voting rights.

SPUMS does not run any courses in diving medicine. These are run by various naval and hospital hyperbaric units and the Diving Medical Centre in Brisbane.

Only a few members of SPUMS, and many doctors who are not members, do diving medicals. To the best of our knowledge only one doctor in Australia, Dr Carl Edmonds, practices solely at diving medicine.

John Knight
Editor, SPUMS Journal

ORIGINAL PAPERS

FLYING AFTER TREATMENT FOR DECOMPRESSION ILLNESS: WHEN IS IT SAFE?

Christopher Butler

Introduction

When is it safe for a diver who has sustained an episode of decompression illness (DCI) to ascend to altitude?

In an age when many divers fly to and from their dive locations, this is a common and important question. It has been appreciated since the 1930's that altitude ascent can precipitate or exacerbate symptoms of DCI.[1] However, there is a wide range of opinion regarding when this altitude ascent is safe, and this variability is due to a lack of data from adequate clinical studies.

The objective of this paper is to review the literature and to suggest safe and supportable advice that can be given to divers in this situation.

The clinical problem

A high proportion of divers who suffer DCI have flown to their diving location. A review of patients treated for DCI at Townsville from 1977 to 1988 showed that 26% were from overseas.[2] A further 14% were from interstate. It is therefore common to have to advise divers on when they can fly after treatment for DCI. These divers usually feel well and are keen to travel home, so any delay of flying needs to be justified.

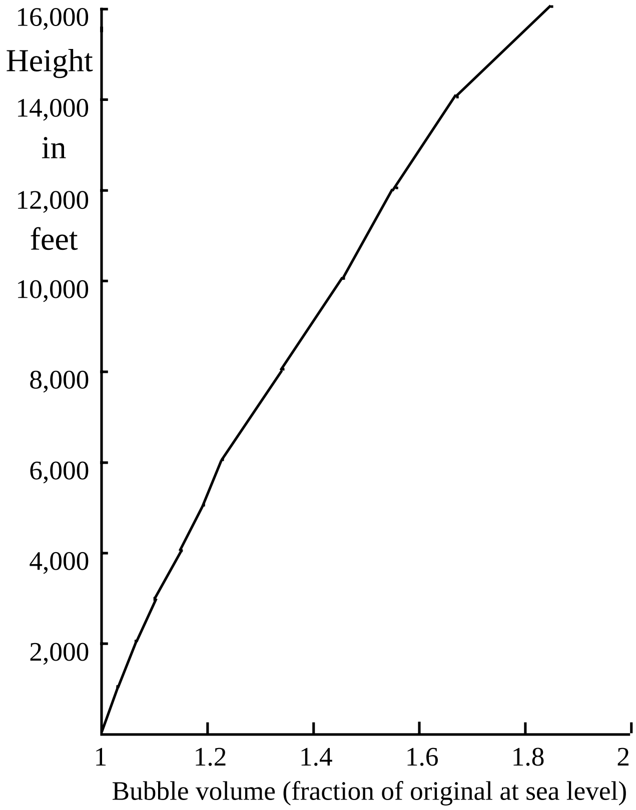
Bubble effects with altitude

Ascent to altitude results in a decrease in the ambient pressure. Most modern airliners, for reasons of fuel efficiency and weather conditions, fly at an altitude above 9,000 m (30,000 ft). To prevent hypoxia and for passenger comfort, the aircraft cabin is usually pressurized to give an equivalent altitude of 2,440 m (8,000 ft), at which the ambient pressure is 0.74 bar.[3]

Such a decrease in ambient pressure will cause any gas bubble present in a tissue to increase in volume by 35% according to Boyle's Law (figure 1). This expansion corresponds to an increase in bubble radius of 10.6%. Such changes in bubble size may appear small, but cases have been documented where such altitude exposures provoked DCI in previously asymptomatic divers.[4]

FIGURE 1

BUBBLE EXPANSION WITH ALTITUDE



Flying after diving in asymptomatic divers

Asymptomatic divers who have been exposed to reduced ambient pressure after a 3 hour surface interval have had venous bubble formation detected by Doppler at altitudes of 1,000 m to 3,000 m.[5] Similarly, the provocation of DCI with altitude exposure has been shown experimentally in dogs.[6] This risk to the asymptomatic diver decreases rapidly during the 24 hours following the dive.[7]

Those who go to altitude soon after diving are likely to have tissues that are supersaturated with inert gas. Ascent makes the development of bubbles, or the enlargement of previously asymptomatic bubbles, more likely. The reduction of this risk over a relatively short time span can best be explained by the elimination of much of the inert gas load via the lungs.

Conversely, if flying prior to diving is associated with the development of asymptomatic bubbles, the risk of DCI following a subsequent dive may be increased.[8]

This subject has been extensively reviewed recently by Sheffield,[9] with recommended surface intervals for flying after asymptomatic diving.

Flying after diving followed by DCI

The problem of flying after the development of clinical DCI differs from the situation above in two important ways. First the patient with symptomatic DCI must have developed bubbles and tissue damage before altitude exposure. Secondly, the safe time period before altitude ascent for those suffering from DCI suggested by some authors (up to 4 weeks)[10] is considerably longer than that for asymptomatic divers discussed above. Such an in interval should allow the inert gas dissolved in the body to equilibrate with the atmospheric partial pressure of that gas. This means that it is essential to know how long bubbles can exist in tissues following their development.

Logically, it might be expected that bubbles could exist in a tissue for a relatively short time, probably for no more than several half times for that particular gas in that particular tissue. This expectation is reinforced by both mathematical and in vitro models of bubble dissolution.[11] Evidence exists however that this is not always the case, and that bubbles may remain in tissues for much longer.

It has long been appreciated that the presence of X-ray "streaking" in periarticular tissues can correlate with DCI.[12] Hills and Le Messurier (unpublished observations) followed up a diver in Adelaide using X-rays, and found that asymptomatic tissue bubbles could still be identified 22 days after his bends-provoking dive.

Evidence also exists regarding the efficacy of delayed treatment of DCI. Divers with symptomatic DCI who delay recompression for up to 10 days can still respond with full resolution of their symptoms.[13] This suggests that they still had tissue bubbles. These time periods far exceed any of the theoretical half times for gas-tissue kinetics that are used for the calculation of dive tables.

Case reports

There are few case reports of recurrence of DCI following altitude ascent. This is probably due to these recurrences being both infrequent and under-reported. The United States Air Force (USAF) reported no cases of recurrent altitude DCI following treatment in the period 1970-1980.[14] This is despite a policy of allowing flying when airmen became asymptomatic, without stipulating a specific period of grounding.

However, other reports indicate that such a policy is too liberal. Recurrent episodes of altitude DCI can be considered significant and due to the presence of residual bubbles if the recurrent symptoms mimic the initial symp-

TABLE 1

SUMMARY OF OPINIONS FOR FLYING AFTER DCI

Author or Organization	Suggested Time interval
Rayman & McNaughton (USAF)[14]	Once asymptomatic and treatment is completed. No specific time given.
Davis[18]	24 hours after treatment of Type 1. 72 hours after treatment of Type 2.
United States Navy[19]	24 hours after surfacing for Type 1. 48 hours after treatment of Type 2. Minimum 72 hours if symptoms persist.
Professional Association of Diving Instructors (PADI)[20]	72 hours following treatment of DCS.
Williamson J (Personal communication)	28 days following treatment.
Arthur and Margulies[10]	1 week after onset of Type 1. 30 days after onset of Type 2.
Bassett[21]	48 hours after treatment of symptoms resovled. At discretion of diving medical consultant if unresolved.
AS 2299[22]	Not greater than 300 m for 7 days.

toms and the recurrence develops at a lower altitude than the initial episode. This is even more significant if the recurrence occurs at an altitude below 18,000 ft (5,400 m)[15], which is the usually accepted lower limit for altitude DCI.

A series of cases of altitude DCI reported by Allan[16] showed recurrent DCI symptoms developing at up to 2 weeks after their initiation. These recurrences were considered by that author to be the result of previous injury, but bubbles had probably remained over that time to produce a recurrence of identical symptoms. Another case of recurrence at 3 days after resolution was reported by Furry.[17]

An unreported series of 4 divers treated at the Royal Adelaide Hospital had recurrence of their symptoms with ascent to 300 m (1,000 ft), 2 days after their last treatment. These cases indicate that some divers require a delay of at least several days after symptom resolution before ascent to altitude can be tolerated.

Present recommendations

Current opinion about when a diver treated for DCI can fly varies greatly. Many authors and organizations recommend very different intervals. Given the lack of data, substantiation of any of these views is impossible. Table 1 gives a summary of these opinions. A review by Sheffield demonstrates a similar variability of opinion.[9]

Neurological effects

It is important to consider what constitutes the clinically asymptomatic treated diver. A review of divers treated for DCI was conducted by the Royal Australian Navy.[23] This study involved a clinical neurological examination, a series of psychological tests, a 19 lead EEG and a CT scan of the head. Clinical resolution of symptoms occurred in 84 of the 87 treated divers. The EEG follow up demonstrated that, of 46 divers, at one week 22 and at one month 8 divers had abnormal EEGs. It is not known whether these residual abnormalities were due to the continuing presence of tissue bubbles, the haematological abnormalities subsequent to bubble formation, or the residual effects of damaged nerve tissue. Regardless of the exact pathogenesis of such changes, this data would indicate that 1 week after treatment may be too short a convalescence before altitude exposure.

Type 1 versus Type 2 disease

Three of the opinions presented in Table 1 vary the management of DCI according to the Type 1 and Type 2 categories as originally proposed by Golding et al.[24] This symptomatic classification was suggested to differentiate "simple" limb bends from the "more serious" neurological and cardiopulmonary manifestations of DCI. Recent reviews of divers suffering DCI in Australia suggest that most divers with limb bends have neurological manifestations of their disease.[2,25] This is further substantiated when these "pain only" sufferers are subjected to EEG examination.[23] This would indicate that no attempt should be made to differentiate, on the basis of presenting symptoms, when divers should ascend to altitude.

Conclusions and recommendations

Because of the lack of systematic patient follow-up and of controlled studies, it is difficult to estimate the frequency of DCI recurrence with ascent to altitude, although the USAF review would suggest that it is uncommon.[14] In this context, it is not surprising that opinions about the safe time interval before altitude ascent are inconsistent. I have found unpublished evidence that asymptomatic bubbles can exist in tissues for periods of up to 3 weeks and published evidence that such stable bubbles may lead to a recurrence of DCI symptoms.[16,17] There is also evidence that treated asymptomatic divers have EEG abnormalities that resolve during the month after treatment.[23]

As it is impossible to identify which divers will have a prolonged risk of recurrence, it would seem prudent to recommend a period of 4 weeks from the end of treatment until ascent is permitted. Many divers would consider such a time interval to be too restrictive and as such would be likely to fly earlier and accept an increased risk of recurrence. However, although this interval is arbitrary, it is longer than any reported bubble survival in tissue, as well as being longer than the interval reported to be associated with recurrences. There is also good supporting evidence that this advice should not be varied on the basis of presenting symptoms.

The recommendation is based on limited information, mainly from isolated case reports. It is impossible on present information to quantify the risk of recurrence of DCI with flying after shorter periods of convalescence, or at what altitude these risks become significant.

It is important that a controlled follow-up study of divers suffering DCI is carried out. The information required is (a) the time from end of treatment to altitude ascent, (b) the altitude ascended to, and (c) the presence of any recurrent symptoms. As most treated divers in Australia cannot be reviewed by the treating Hyperbaric Unit, such a study would have to rely on patient reporting, probably by questionnaire. Such a study would allow some quantification of the risk of DCI recurrence.

With the increasing popularity of recreational diving and the greater mobility of diving populations, flying after diving will continue to occur with greater frequency. Consequently, detailed follow-up studies of treated divers are now essential.

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This paper was written as a requirement for the Diploma of Diving and Hyperbaric Medicine, which was awarded to Dr Butler.in July 1992

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ON NO-STOP TIME LIMITS, SAFETY STOPS AND ASCENT RATES

Bruce Wienke

Introduction

The past ten years, or so, have witnessed a number of important changes in diving protocols and table procedures, such as shorter no-stop time limits, slower ascent rates, discretionary safety stops, repetitive dive profiles requiring all dives to be shallower than the one before, multi-level techniques, both faster and slower tissue half-times controlling repetitive dives, lower critical tensions (M-values) and longer flying-after-diving surface intervals. Stimulated by

Doppler technology, decompression meter development, theory, statistics, or safer diving concerns, these modifications affect a gamut of activity, spanning bounce to multi-day diving. Of these changes, conservative no-stop time limits, non-decompression safety stops and slower ascent rates (less than the standard 18m (60 ft)/min) are much in vogue, and deserve a closer look. As it turns out, there is good support for shorter no-stop limits, safety stops, and slow ascent rates on practical, experimental and theoretical grounds.

Discretionary protocols

Spencer[1] poineered bubble counting by the use of Doppler. His results, showing many bubbles at no-stop limits, led him to suggest reductions in the no-stop limits of the US Navy (USN) tables. A reduction in the M value, of the order of a repetitive group or two at each depth in the tables (1-4 ft in critical tensions), was recommended to lower bubble counts. Others have made similar recommendations over the past 15 years.

Smith and Stayton[2] noted marked reductions in precordial bubbles when ascent rates were cut from 18 m (60 ft)/min to 9 m (30 ft)/min. In similar studies, Pilmanis[3] and Neuman, Hall and Linaweaver[4] witnessed an order of magnitude drop in venous gas emboli (VGE) counts in divers making short safety stops following bounce exposures to 30m (100 ft).

An American Academy of Underwater Sciences (AAUS) workshop on repetitive diving, recorded by Lang and Vann,[5] and Divers Alert Network (DAN) statistics[6] suggest that present diving practices become riskier with increasing exposure time and pressure (depth) This evidence has encouraged the development of ancillary safety measures for multi-level, repetitive and multi-day diving. Dunford, Wachholz, Huggins and Bennett[7] noted persistent Doppler scores in divers performing repetitive, multi-day diving, suggesting the presence of VGE in divers, all the time, under such loadings.

Ascent rates, safety stops, decompression computers and altitude diving were also the subject of extensive discussion at workshops and technical forums sponsored by the American Academy of Underwater Sciences and the Undersea and Hyperbaric Medical Society (UHMS) and have been summarized by Lang and Hamilton,[8] Lang and Egstrom[9] and Sheffield.[10] The discussions culminated in a set of recommendations, based on standard Haldane[11] table and meter procedures, even for exposures not exceeding time limits nor critical tissue tensions.

The upshot of these studies, workshops, discussions and tests is a set of discretionary protocols, not necessarily endorsed in all diving sectors, but which might be summarized as follows:

1 reduce no-stop time limits a repetitive group, or two, below the standard USN limits;
2 keep ascent rates below 18 m (60 ft)/min, preferably slower and required to be slower at altitude;
3 limit repetitive dives to a maximum of three per day, none exceeding 30 m (100 ft);
4 avoid multi-day, multi-level, or repetitive dives to increasing depths;
5 wait 12 hours before flying after no-stop diving, 24 hrs after heavy diving (taxing, near decompression, or prolonged repetitive) activity, and 48 hrs after decompression diving;
6 avoid multiple ascents to the surface and short repetitive dives (spikes) with surface intervals less than 1 hour;
7 surface intervals of more than an hour are recommended for repetitive diving;
8 safety stops for 2-4 minutes in the 3-9 m (10-20 ft) zone are advisable for all diving, but particularly for deep, near 30 m (100 ft), repetitive and multi-day exposures;
9 do not dive at altitudes above 10,000 ft using modified conventional tables, or linear extrapolations of sea-level critical tensions;
10 in short, dive conservatively, remembering that tables and meters are not bends-proof.

Procedures such as those above are prudent, theoretically sound and accepted safe diving practice. Ultimately, they can all be linked to bubble decompression models, and our interests here are no-stop limits, safety stops and ascent rates. In considering these items, a quick look at bubbles and related dynamics is first necessary.

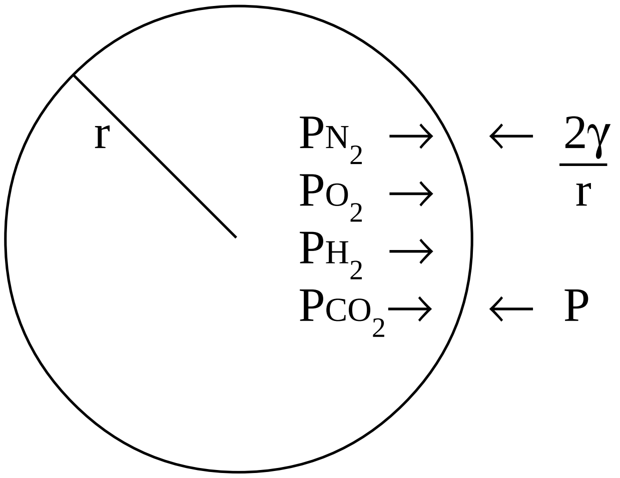
Bubble dynamics

Internal pressures in bubbles exceed ambient pressures by amounts equal to the effective surface tensions of the bubbles (Figure 1). To eliminate bubbles, or reduce their growth, increased ambient pressure is required, not only to restrict the size, but also to drive gas out of the bubble by diffusion, and across the tissue-bubble interface (Figure 2). The shorter the desired time of elimination, the greater must be the ambient pressure. Experiments conducted in decompressed gels, notably by Yount and Strauss,[12] Kunkle and Beckman,[13] and Yount,[14,15] have been illuminating, showing that the smaller the bubble, the shorter the dissolution time (Figure 3).

The implications for diving are clear. In the presence of even asymptomatic bubbles increased off-gassing pressure is prudent. At any pressure, the length of time required to dissolve bubbles of 250 micron diameter is significantly shorter than that required to dissolve larger bubbles. Immediate recompression, within less than 5 minutes, is adequate treatment for bubbles less than 100 microns in diameter and forms the basis for Hawaiian emergency in-water recom-

FIGURE 1

BUBBLE PRESSURE BALANCE



The total gas pressure, P_t within an air bubble equals the sum of ambient pressure, P, plus effective surface tension, 2γ/r, according to,

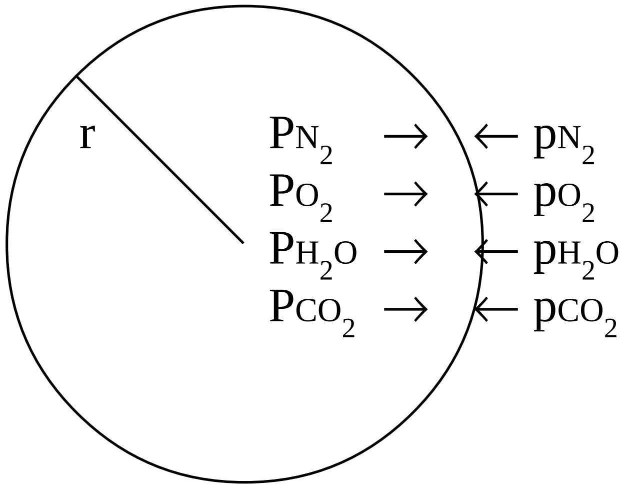
$$P_t = P + 2\gamma/2$$

$$P_t = PO_2 + PN_2 + PH_2O + PCO_2$$

At small radii, surface tension effects are large, while at large radii effects of surface tension vanish. Effective surface tension is the difference between Laplacian (thin film) tension and skin (surfactant) tension. Stabilized nuclei exhibit zero effective surface tension, so that total gas pressures and tensions are equal. When nuclei are destabilized (bubbles), any gradients between free and dissolved gas phases will drive the system to different configurations, that is, expansion or contraction, until a new equilibrium is established.

FIGURE 2

BUBBLE GAS DIFFUSION



An air bubble in hydrostatic equilibrium will grow or contract, depending on its size and any relative gradients between free gas in the bubble and dissolved gas in tissue. Gradients are inward if tissue tensions exceed bubble gas presures and outward if bubble gas pressures exceed tissue tensions. A critical radius, r_c, separates growing from contracting bubbles for a given set of pressures. The critical radius depends on the total tension, p_t, ambient pressure, P, and effective surface tension, γ,

$$r_c = \frac{2\gamma}{p_t - P}$$

$$p_t = pN_2 + pO_2 + pH_2O + pCO_2$$

where growth occurs for $r>r_c$ and contraction for $r>r_c$. Some stabilized gas micronuclei in the body can always be excited into growth by pressure changes (compression-decompression).

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pression procedures. If one assumes that gel and tissue bubbles respond to pressure in much the same manner, these facts support the arguments for safety stops when conventional tables are pushed to the limits of times or on repetitive dives.

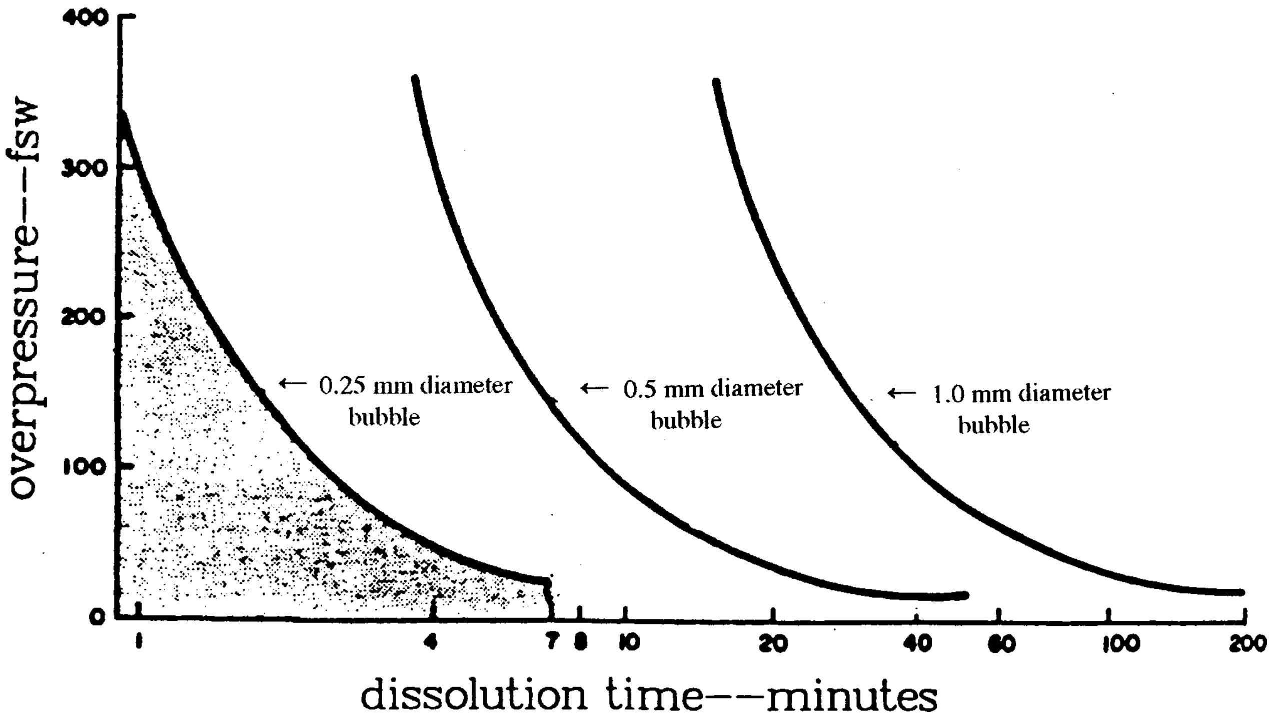
Bubbles, which are unstable, might grow from micron size gas nuclei, formed and stabilized over short periods of time and resisting collapse due to permeable skins of surface-activated molecules (surfactants), or possibly by reduction in surface tension at tissue interfaces or crevices. Gas nuclei seem to pervade all manner of fluids and their existence in blood serum and egg albumin has been established by Yount and Strauss.[12] Families of micronuclei vary in size and surfactant content.

Micronulcei theoretically are small enough to pass through the pulmonary vascular bed filters, yet dense enough not to float to the surfaces of their environments, with which they are in both hydrostatic (pressure) and diffusion (gas flow) equilibrium. When nuclei are stabilized their net surface tension is zero. Then all pressures and gas tensions are equal.

However, on decompression, these stable pockets, which have had extra gas diffuse into them during the period of compression, can be destabilized by the reduced ambient pressure, so that net surface tension is no longer zero, and subsequently they can enlarge into bubbles, which will expand as surrounding gas diffuses into them. The rate at which bubbles grow, or contract, depends directly on the difference between tissue tension and the local ambient pressure, effectively the supersaturation gradient. At some point in time, a critical volume of bubbles, or separated gas, is established and bends symptoms become statistically more probable.

FIGURE 3

DISSOLUTION TIME FOR GRADED BUBBLES



Bubbles develop and grow over longer time scales than nuclear stabilization. Yet, the rapid dissolution of bubbles in decompressed saturated gelatin (and the body proper) requires immediate and adequate repressurization. The absolute length of time required to dissolve bubbles with given overpressure is directly proportional to the size of the bubble. Obviously, the smaller the bubble, the shorter the time needed to dissolve that bubble at any overpressure. The bubbles studied in this experiment by Kunkle and Beckman grew to approximately 1 mm in 5 hours, starting from stabilized micronuclei. Such experiments have provided vital information, corroborating nucleation and bubble theories in vitro.

Nucleation

Nucleation-bubble theory is consistent with various diving observations. Divers can significantly increase tolerance against bubble formation and therefore bends, by following three simple practices, originally suggested by Strauss,[16] Evans and Walder,[17] and many others:

1 make the first dive a deep, short (crush) dive, to compress micronulcei down to a smaller, safer size;
2 make succeeding dives progressively shallower, that is diving within the crush limits of the first dive and so minimizing excitation of smaller micronuclei;
3 make frequent dives (like every other day), to deplete the number of micronulcei available to form bubbles.

The mechanics of nucleation, stabilization and bubble growth are fairly complex, with stabilization mechanisms only recently quantified. Source and generation mechanisms before stabilization are not well understood. Some candidates include cosmic radiation and charged particles, dissolved gases in the fluid we drink, lymph draining from tissues into veins, collisional coalescence, blood turbulence and vortices, exercise, the stomach and the thin air-blood endothelium in the lungs. More direct methods of bubble formation are also certainly possible. Cavitation, produced by the rapid tearing or moving apart of tissue interfaces, is a candidate, as well as surface friction (tribonucleation). Crevices in tissues may form or trap gas phases, with later potential for release. Vortices in blood flow might cause small microbubbles. Whatever the production and stabilization mechanisms of micronuclei, once destabilized the ensuing bubbles follow the dynamic growth and contraction patterns shown in Figures 1 and 2.

Stable or unstable, the presence of copious microbubbles in the venous circulation would affect dissolved gas elimination adversely, possibly impairing the lungs or escaping into the arterial network. The presence of bubbles in the arterial circulation might result in emboli. The chokes, a serious form of decompression sickness, is thought to be due to bubbles clogging the pulmonary circulation. Cerebral decompression sickness is believed by some to be due to arterial emboli. Microbubbles in the venous circulation would render gas uptake and elimination more asymmetrical than it normally is by slowing down elimination. Displacing blood, microbubbles would reduce the effective area and volume for tissue-blood gas exchange.

Sites

Bubbles may hypothetically form in the blood (intravascular) or outside the blood (extravascular). Once formed, intravascularly or extravascularly, a number of critical insults are possible. Intravascular bubbles may induce blood sludging and chemistry changes. Circulating gas emboli may clog the pulmonary filters, and occlude the arterial flow. Extravascular bubbles may remain locally in tissue sites, enlarging by diffusion from adjacent supersaturated tissue, and compress nerves or compress a blood vessel and occlude it causing ischaemia. Extravascular bubbles can also pass through capillary walls and so enter veins, at which point they become intravascular bubbles.

Many doubt that bubbles form in the blood directly, but intravascular bubbles have been seen in both the arterial and venous circulation after very rapid decompression, with vastly greater numbers detected in venous flow known as venous gas emboli(VGE). Ischaemia resulting from bubbles caught in the arterial network has long been invoked as a cause of decompression sickness. Since the lungs are effective filters of venous bubbles, arterial bubbles must either form in the arteries or have bypassed the lung. The more numerous venous bubbles are suspected to form first in lipid tissues drained by the veins. Lipid tissue sites also posses very few nerve endings, possibly masking critical insults. Veins being thinner than arteries, are more susceptible to extravascular gas penetration.

Extravascular bubbles may form in aqueous (watery) or lipid (fatty) tissues in principle. For all but extreme, or explosive, decompression bubbles are seldom observed in muscles or liver tissue. Most gas is seen in fatty tissue, not surprisingly considering the five-fold higher solubility of nitrogen in lipid tissue compared to aqueous tissue. Since fatty tissue has few nerve endings, tissue deformation by bubbles is unlikely to cause pain locally. On the other hand, formations of large volumes of extravascular gas which then enters the capillaries could induce vascular damage, depositing both fat and bubbles into the circulation as has been seen in animal experiments. If mechanical pressure on nerves is a prime candidate for the critical insult, then tissues with high concentrations of nerve endings, such as tendon or spinal cord, are candidate structures. The spinal cord with high nerve density and much lipid insulating axons and a high blood flow is a good environment for bubble formation and growth as well as an obvious site for mechanical insult.

VGE

Sound reflected off a moving boundary undergoes a shift in acoustic frequency, the so-called Doppler shift. The shift is directly proportional to the speed of the moving surface (component in the direction of sound propagation) and the acoustic frequency of the wave and inversely proportional to the sound speed. Acoustic signals in the megahertz range, termed ultrasound, have been directed at moving blood in the pulmonary artery, where blood flow is fastest (near 20 cm/sec), with resulting Doppler shifts, in the form of audible chirps, snaps, whistle, and pops, noted and recorded. Sounds heard in divers have been ascribed to VGE as all venous blood passes through the pulmonary artery. In vitro simulations have established minimum bubble detection size as a function of blood velocity. Coalesced lipids, platelet aggregates and agglutinated red blood cells formed during decompression also pass through the pulmonary circulation, but are less reflective than bubbles, and are usually smaller. Bubbles with radii in the 20 micron range represent the smallest dectable by Doppler using signals of a few megahertz.

As blood constitutes no more than 9% of the total body capacity for dissolved gas, the volume of the venous circulation cannot account for the amount of gas detected as VGE. VGE are not the direct cause of bends per se, unless they block the pulmonary circulation, or pass through the pulmonary filters and enter the arterial system to lodge in critical sites. The likely culprits are bubbles forming in fatty tissues surrounding nerves or in poorly perfused tissues such as tendons. Intravascular bubbles probably first form at extravascular sites. According to Hills[27] electron micrographs have shown bubbles breaking into capillary walls from adjacent lipid tissue beds in mice. The Lambertsen[28] studies of vascular disruption, subcutaneous bruising and venous emboli point to bubble formation in tissues as the culprit. Fatty tissue, possessing few nerve endings, is thought to be an extravascular site of bubble formations.

No-stop limits

Ultrasound techniques for monitoring moving gas emboli in the pulmonary circulation are popular today. Silent bubbles, a term applied to the VGE detected in sheep undergoing bends-free USN table decompressions by Spencer and Campbell,[18] were a first indication that asymptomatic free gas was present in blood, even under bounce dive loadings. Similar results were reported by Walder, Evans and Hempleman.[19] After observing and contrasting VGE counts for various no-stop exposures at depth, Spencer[1] suggested that no-stop limits be reduced below the USN (Workman) table limits. These shorter times produced a 20% drop in VGE counts compared to the USN limits. The newer no-stop limits, t, satisfy a reduced Hempleman relationship,[20,21] that is, $dt^{1/2} \leq 465$ ft min,$^{1/2}$ where d is depth.

TABLE 1

COMPARATIVE NO-STOP TIME LIMITS IN MINUTES

Depth msw	Depth fsw	Workman	Spencer	Bühlmann	Wienke-Yount and Hoffman
9	30		225	290	250
12	40	200	135	125	130
15	50	100	75	75	73
18	60	60	50	54	52
21	70	50	40	38	39
24	80	40	30	26	27
27	90	30	25	22	22
30	100	25	20	20	18
33	110	20	15	17	15
36	120	15	10	15	12
39	130	10	5	11	9

Table 1 compares no-stop time limits according to the Workman,[22] and more recent Spencer,[1] Bühlmann,[23] and Wienke-Yount/Hoffman[24,25] algorithms. Further reduction in time limits would seem to increase safety. Limits much below the Spencer, Bühlmann and Wienke-Yount-Hoffman times would restrict repetitive diving, but at the expence of bounce diving.

Statistics gathered by Gilliam[26] suggest that divers using conservative time limits (Bühlmann based diving computer) have compiled an enviable track record, with an incidence of decompression sickness below 0.01% in combined table and meter usage. Many regard such an incidence rate as acceptable.

Another way to restrict repetitive and multi-day diving, suggested by bubble models employing the critical phase volume trigger point, is to reduce the permissible supersaturation tensions on successive dives. This does not restrict no-stop time limits for single bounce dives. The permissible, or critical, tensions are the maximum dissolved gas partial pressures allowed in each tissue compartment and the critical phase volume is the maximum allowable separated gas volume present in all the compartments. The reduced gradient bubble model[24] (RGBM) is one such dual phase model. It systematically reduces critical tensions on repetitive dives by constraining both dissolved and free phase gas build-up.

Table 2 lists the corresponding maximum (critical) surfacing tensions (M_0) for four algorithms. Three, the Workman, Spencer and Bhülmann, have fixed Haldane-model values. The fourth is the variable bubble model (RGBM). The critical tensions in the latter three algorithms are smaller, by some 0.3-1.2 msw (1-4 ft), than the Workman (USN) values, effectively shortening the no-stop time limits a group, or two, compared with the USN tables.

The numbers of VGE detected with ultrasound Doppler techniques can be correlated with no-stop limits and the bubble free limit can then used to fine tune the critical tension matrix for select exposure ranges. However fundamental issues are not necessarily resolved by VGE measurements.

What has not been established is the link between VGE, possible micronuclei and bubbles in critical tissues. Any such correlations of VGE with tissue micronulcei would unquestionably require considerable first-hand knowledge of nuclei size distributions, sites and tissue thermodynamic properties. Recent Doppler studies and correlations by Powell and Rogers,[29] Eckenhoff,[30] and Sawatzky and Nishi[21] do hint that the variability in gas phase formation, is probably less than the variability in symptom generation.

Whatever the origins of VGE, procedures and protocols which reduce gas phases anywhere in the body deserve attention, on the assumption that venous bubbles are a reflection of tissues bubbling. The moving Doppler bubble may not be the bends bubble, but perhaps the difference may only be its site. The numbers of VGE may reflect the state of critical tissues where decompression sickness does occur. Studies based on Doppler detection of VGE are still the only viable means of monitoring free gas phases in the body.

Ascent rates and stops

The effects of slower ascent rates and safety stops, in the context of dissolved gas models, are consistent with bubble mechanics. Both reduce bubble growth rate and bubble formation because of greater off-gassing at the end of the dive. That is a strong endorsement for the practice. Some regard slower ascent rates, safety stops and increased bubble off-gassing pressures as treatment for bubbles, par-

TABLE 2

COMPARATIVE SURFACING CRITICAL TENSIONS (M_o)

Half-time minutes	Workman Mo (fsw)	Spencer M_o (fsw)	Buhlmann M_o (fsw)	Wienke-Yount and Hoffman M_o (fsw)
5	104	100	102	100-70
10	88	84	82	81-60
20	72	68	65	67-57
40	58	53	56	57-49
80	52	51	50	51-46
120	51	49	48	48-45

ticularly near the surface where ambient pressure reduction enhances bubble growth. Gas nucleation theory and experiments show that on any given dive (compression-decompression), families of micronuclei, larger than a critical (minimum) size, are excited into bubble growth, so one must pay attention to free phase (bubble) development throughout the dive. Experiments and calculations suggest that slow ascent rates and shallow, short stops not only reduce bubble build-up, but also reduce dissolved gas in faster tissues. Reducing fast tissue dissolved gas is important for deeper diving. The reasons are rooted in nucleation and bubble mechanics, but some empirical diving practices deserve attention before we turn to illustrative phase model calculations.

Diving practices

Utilitarian procedures, entirely consistent with phase mechanics and bubble dissolution time scales, have been developed, under duress and with trauma, by Australian pearl divers and Hawaiian diving fishermen, for both deep and repetitive diving with possible in-water recompression for decompression hits. While the science behind such procedures was not initially clear, the operational effectiveness was always noteworthy and could not be discounted easily. Later, the rationale, essentially recounted above, became clearer.

Pearling fleets, operating in the deep tidal waters off northern Australia, employed Okinawan hard hat divers who regularly dived to depths of 55 m (180 ft) for as long as one hour, twice a day, six days per week and for ten months a year. Driven by economics and not by science, these divers developed decompression schedules empirically. As reported by LeMessurier and Hills,[32] deeper decompression stops, but shorter decompression times than required by Haldane theory, were characteristics of their profiles. Such profiles are entirely consistent with minimizing bubble growth and the excitation of nuclei. Being pulled up by hand they had slow ascent rates. There was a high incidence of decompression sickness, but less than would have been expected. Years later Dr Carl Edmonds, an Australian, devised a simple, but very effective, in-water recompression procedure for use in isolated places. The diver is taken back down to 9 m (30 ft) on oxygen for a minimum 30 minutes in mild cases, or longer in severe cases, and decompressed at 1 m every 3 minutes. The increased pressure helps to compress bubbles, while breathing pure oxygen maximizes inert gas washout (elimination).

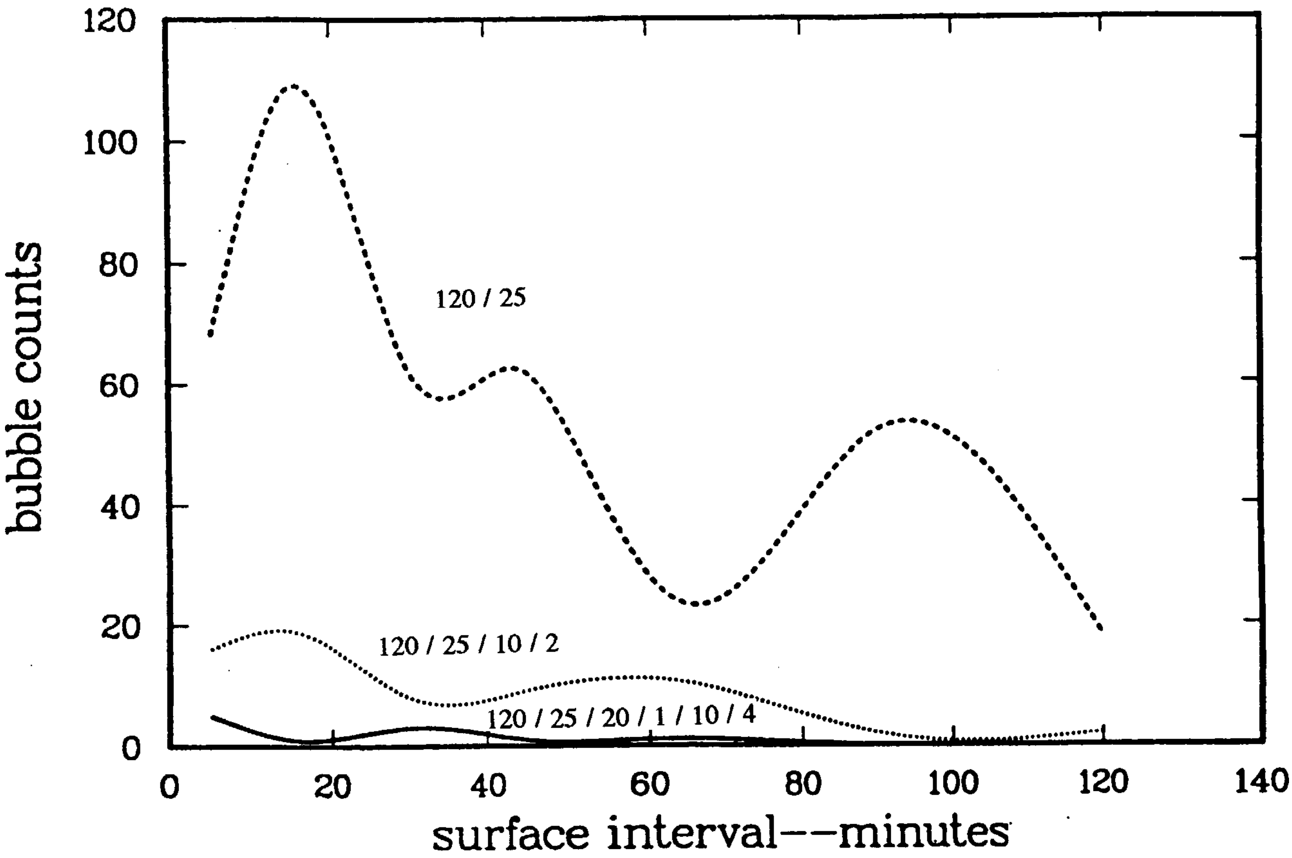
Somewhat similar schedules have evolved in Hawaii, among diving fishermen, according to Farm, Hayashi and Beckman.[33] Harvesting the oceans for food and profit, Hawaiian divers make between 8 and 12 dives a day to depths beyond 105 m (350 ft). Profit incentives induce divers to take risks by exceeding the bottom time in conventional tables. Three repetitive dives are usually necessary to net a school of fish. Consistent with bubble and necleation theory, these divers make their deep dive first, followed by shallower excursions. A typical series might start with a dive to 66 m (220 ft), followed by 2 dives to 36 m (120 ft) and culminate in 3 or 4 more excursions to less than 18 m (60 ft). Often, very short or zero surface intervals are clocked between dives. Such profiles are incompatible with Haldane tables, but, with proper reckoning of bubble and phase mechanics, appear possible. With ascending profiles and suitable application of pressure, gas seed excitation and any bubble growth are constrained within the body's capacity to eliminate free and dissolved gas phases. In a broad sense, the final shallow dives have been tagged as prolonged safety stops and the effectiveness of these procedures has been substantiated in vivo (dogs) by Kunkle and Beckman.[13] If the diver develops decompression sickness immediate in water recompression, using air, is undertaken.

Wet and dry tests

While the above practices developed by trial-and-error, VGE measurements, performed off Catalina by Pilmanis[3] on divers making shallow safety stops, fall into a

FIGURE 4

REDUCTION IN DOPPLER BUBBLE COUNTS FOLLOWING SAFETY STOPS



Safety stops have considerable impact on Doppler sounded VGE measurements, according to Pilmanis. Following a dive to 30 m (100 fsw) for 25 minutes, the top curve registers VGE counts over increasing surface time. The lower two curves depict the count after a brief stop for 2 minutes at 3 m (10 fsw), and then 1 minute at 6 m (20 fsw) followed by 4 minutes at 3 m (10 fsw). Reductions by factors of 4-6 are apparent. Whether VGE correlate with susceptibility to DCS or not, bubble reduction in the pulmonary circulation is impressive with shallow safety stops.

more scientific category. Bubble counts following bounce exposures near 30 m (100 ft), with and without stops in the 3-6 m (10-20 ft) range, showed marked reductions (factors of 4 to 5) in VGE when stops were made (Figure 4). If, as some suggest, VGE in bounce diving correlate with bubbles in sites such as tendons and ligaments, then safety stops probably minimize bubble growth in such extravascular locations. In these tests, the sample population was small, but similar findings were also made by Neuman, Hall and Linaweaver.[4]

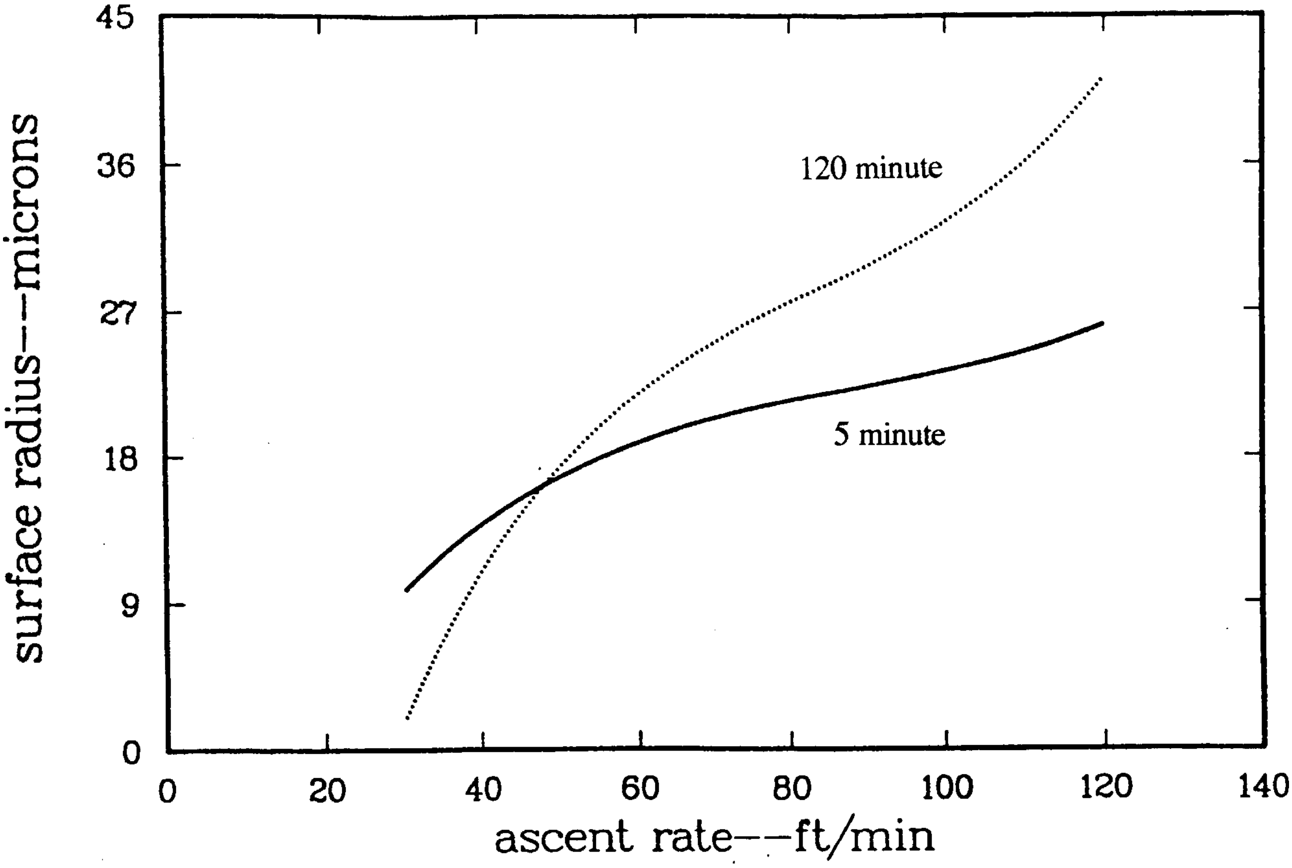
Smith and Stayton,[2] in goat studies, have shown that the incidence of precordial bubbles was greatly reduced when ascent rates were cut from 18 m (60 ft)/min to 9 m (30 ft)/min. Across a variety of decompression profiles, venous bubbles were greatly reduced by slower ascent rates and deeper initial decompression stops than are required by the USN tables. Venous bubbles eliminated during short, deeper stops probably originate in fast tissues. Eliminating these bubbles early in the decompression would allow more slowly exchanging tissues to desaturate safely, while also minimizing the number of arterial emboli possibly remaining after intracardiac shunting, or transpulmonary escape of VGE.

Phase calculations

Theoretically, growth minimization and free phase elimination also recommend slow ascents. Figure 5 plots surfacing radius of an initially small bubble (r = 0.36 microns), held in both fast (5 minute) and slow (120 minute) saturated compartments at a depth of 36 m (120 ft), as a function of constant ascent rate, employing a bubble growth

FIGURE 5

BUBBLE GROWTH WITH VARYING ASCENT RATE



The rate at which bubbles grow on ascent depends on their size and surface tension and the average difference between tissue tension and ambient pressure. For bubbles larger than a certain critical (cutoff or minimum) radius, faster ascents in the presence of elevated gas tensions in surrounding tissue sites tend to support growth, because average ambient pressure, P, is lessened by fast ascent. Increasing ambient pressure always tends to restrict simple bubble growth, since internal bubble pressure is always greater than ambient pressure by an amount, $2\gamma/r$. In this calculation, $2\gamma/r = 8.3$ fsw/micron and unit solubility, concentration and diffusivity employed for simplicity. One notes that the growth rate in the 5 minute compartment is less than in the 120 minute compartment. The faster compartment off-gases more rapidly during any ascent, presenting a lower average tension and weaker diffusion gradient for growth.

equation. The results plotted are also typical for actual bounce, multi-level and repetitive diving profiles and show growth minimization with slow ascent dueincreased average ambient pressure.

Using tissue bubble growth equations, Gernhardt, Lambertsen, Miller and Hopkins[34] have correlated bubble sizes with statistical risk of decompression sickness. One result of that analysis is a risk curve which increases with surfacing bubble radius, pointing to the efficacy of slow ascent rates and safety stops, which reduce surfacing bubble radii (Figure 5).

Discussions at the American Academy of Underwater Sciences Ascent Workshop,[9] suggested discretionary safety stops for 2-4 minutes in the 3-6 m (10-20 ft) zone. Supporting calculations, recorded by Wienke[35] and summarized in Table 3, support the bases of the suggestions. Relative changes in three computed trigger points,[21] tissue tension, separated phase volume and bubble radius, are listed for six compartment following a bounce dive to 36 m (120 ft) for 12 minutes, with and without a safety stop at 4.5 m (15 ft) for 3 minutes.

Stop procedures markedly restrict bubble and phase volume growth and dissolved gas build-up in the faster tissue compartments, while only creating insignificant dissolved gas build-up in the slow tissues. The reduction in

TABLE 3

RELATIVE CHANGES IN CRITICAL PARAMETERS AFTER SAFETY STOP

Tissue half-time	Tissue tension relative change	Critical volume relative change	Bubble radius relative change
5	-12%	-34%	-68%
10	-11%	-24%	-39%
20	-6%	-11%	-24%
40	-2%	-8%	-18%
80	1%	3%	-2%
120	2%	4%	1%

growth parameters far outstrips any dissolved gas build-up in slow compartments and faster compartments naturally eliminate dissolved gases and bubbles during the stop, which is important for deeper diving when the gas loads are greater. The calculations in Table 3 are illustrative of a broad category of no-decompression bounce and repetitive diving that has been analyzed.

Safety stop time can be added to bottom time for additional conservatism, but the effect of not doing so is small. A stop at 4.5 m (15 ft) for 2 minutes is roughly equivalent to more than halving the standard ascent rate at depths in excess of 36 m (120 ft). Procedures such as this, as well as conservative no-stop time limits, appear beneficial in multi-day, multi-level and repetitive diving. A safety stop near 4.5 m (15 ft) is easier than at 3 m (10 ft) in adverse water conditions, such as surge and surface disturbances. Slower ascent rates afford additional advantages, but safety stops in the 2-4 minute range are easier and theoretically more efficient. Ascent rates slower than 18 m (60 ft)/min and safety stops in the 6-9 m (10-20 ft) zone are becoming routine for recreational and scientific divers.

Generally, bubble growth and excitation are compounded at altitude because of reduced pressure. Bubbles grow faster as they get bigger and as ambient pressure drops. With decreased ambient pressure, bubbles will also expand in accordance with Boyle's Law. Bigger bubbles are not as constricted by Laplacian film tension, while reduced ambient pressure supports a faster rate of tissue gas diffusion into the bubble itself. At altitude, bubble mechanics theoretically exacerbate decompression risk.

The point to be made here is simple. Increased off-gassing pressures are likely to reduce bubble growth rates dramatically in shallow zones, while increasing dissolved gas build-up in the slowest compartments minimally. Fast compartments also off-load gas and bubbles during slow ascents and safety stops, important for deep diving. Slow ascent rates and stops are always advisable, particularly at altitude and in multi-level and multi-day diving.

Summary

A first-principles decompression theory is not available at present. One suspects shortcomings in present approaches and wonders how to enhance their effective implementation.

In the case of the Haldane (dissolved gas) algorithm, the basis of virtually all diving tables and meters up to 1983, there are two problem areas, free phase (bubble) dynamics and bends trigger points. Tissue tensions are not the same as gas pressures in bubbles and elimination gradients for dissolved phases are not the same as gradients for bubbles. With increased exposure, one observes lower tolerance levels to bubbles. With successively deeper profiles, one suspects that there is excitation of greater numbers of gas nuclei into growth, exceeding the body's capacity for bubble elimination.

These considerations may explain the slightly higher bends incidence, observed by hyperbaric specialists, for divers doing multi-day, repetitive and multi-level excursions, in that order of decreasing risk. Bounce diving is relatively free of risk these days, especially when diving within algorithms employing conservative time limits which restrict phase separation. The presence of increasing proportions of gas as bubbles alters and invalidates tables based on dissolved gas models.

Such changes are best assessed by nucleation and bubble models. Safety stops and slower ascent rates correlate in principle with bubble models and tests as effective procedures, restricting bubble growth. No-stop time limit reductions appear prudent, based on Doppler bubble counting experiments. However, further reductions in no-stop time limits, beyond those in current use, do not appear warranted, considering the low incidence of decompression sickness, less than 0.01% in populations employing recent tables and meters with conservative limits.

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Bruce Wienke PhD, is Director of the Computational Testbed For Industry, Los Alamos National Laboratory, Los Alamos, New Mexico 87545, U.S.A.

THE WORLD AS IT IS

In this new feature we print original papers which are neither scientific articles nor editorials but which are considered to be sufficently important or interesting that they should be brought to the attention of members.

IS THE AMA REALLY INTERESTED IN PREVENTIVE MEDICINE ?

These comments are provoked by a letter from Dr Bob Thomas, who was once the Editor of the SPUMS Newsletter and OIC the Royal Australian Navy School of Underwater Medicine, and the letter which he received from the Federal AMA, both of which appear below.

Diving Medical Centre
132 Yallambee Road
Brisbane
Queensland 4074

11th September, 1992

Dear Editor,

I though you would be interested to read the letter enclosed. Obviously the AMA is still playing games and believes that all doctors can be everything to everyone.

I feel that this letter should be passed to the SPUMS Committee for their information. It raises great concern about the suitability of any SPUMS member not appointed by the Executive (and especially one who espouses an AMA dictum opposite to the ideas of SPUMS at Standards Australia Committee meetings, and yet, supposedly, is himself in agreement with SPUMS views) sitting on Standards Committees concerning diving. How can two opposing hats be worn?

In fact, I can see no need whatsoever for the necessity of any AMA representative on such a diving Committee when the AMA represents no collective body of knowledge concerning diving.

I feel that all SPUMS members should be made aware of this AMA stupidity. Can you please publish this letter in the Journal?

Bob Thomas

Australian Medical Association Limited
42 Maquarie Street
ACT 2600

1st September, 1992

Dear Dr Thomas,

I am replying on behalf of the AMA to your letter of August 9, 1992 with which you enclosed an updated list of medical practitioners who have successfully completed a course of instruction conducted by the Diving Medical Centre (Australia) on diving medical examinations.

As you may know from previous correspondence, the AMA has not accepted that a need exists for such certification in the case of doctors who perform fitness examinations for candidates who wish only to undertake sports/recreational scuba diving. While such certification appears desirable in the longer term, the AMA notes the precedent of no <u>required</u> training for designated medical examiners who complete aircrew licensing medicals, even those for airline transport pilots. The AMA is aware of your views, also those of SPUMS, and is represented on the relevant SAA Committee by Dr I.L.Millar. The Association will keep this matter under review.

P.S. Wilkins
Assistant Secretary General
(Health Services)

The SPUMS position on diving medicals is that they should be compulsory before starting to use compressed air underwater and that they should be done by doctors with training in underwater medicine.

This attitude comes from bitter experience of the inadequacy of many medicals done by doctors who knew little, or more probably nothing, about diving medicine and passed people as fit to dive when they should have been told that it was extremely dangerous to go diving. Some of these people died as a result of this failure to assess them properly.

As far as I know only one medical school (Brisbane) has offered a lecture (one) on diving medicine during the six year medical course. The results of a study in 1985[1] of 364 Queensland doctors who did diving medicals showed that their knowledge was abysmal as the answers to the questions about the treatment of common diving accidents hovered around the 50% correct mark, a result to be expected from guessing. Carl Edmonds mentioned three reasons that might explain why many doctors who did diving medicals without training might be so foolish. These were financial reward, not recognising their own limitations and lack of knowledge.

Of the diver instructor organisations only FAUI (now NASDS) and the BS-AC have insisted on medicals before diving. The BS-AC has never recognised the need to use trained doctors. From the late 1970s many FAUI instructors in Victoria insisted that their trainees attend a doctor with diving medicine training, handing out lists of diving doctors to their students.

During the preparation of AS4005.1 there was written into the final draft of the Standard, that the requirement for a medical to be conducted by doctors trained in diving medicine would only come into effect two years after the Standard was promulgated. This was to allow time for doctors who did diving medicals to obtain the necessary training to do them properly.

At the final meeting it was no surprise that the majority of the training organisations did not want medicals to be done by trained doctors. In fact they voted against medicals being compulsory. FAUI (which had then become NASDS) after voting for a compulsory medical, reversed its previous stance of supporting medicals done by trained doctors, subject to the two year delay clause. The AMA member on the Committee, inspite of his own belief that a compulsory medical should be done by a trained doctor, had to vote against that motion because the AMA had told him to. After this meeting Dr Des Gorman, the President of SPUMS wrote to the AMA presidents, Federal as well as State. The replies were most interesting. All three of Dr Edmonds' reasons appear in the letters Dr Gorman received in reply, which we reproduce here.

Medical Society of Victoria Inc.
Australian Medical Association

6th January 1992

STANDARDS AUSTRALIA: RECREATIONAL DIVING

Dear Dr Gorman,

It is our understanding that this matter was handled by the Federal Office of the AMA, and to my recollection no opinion was sought from the Branches.

Accordingly, I have forwarded a copy of your letter to Dr Allan Passmore, General Secretary of the Federal body of the AMA, and have asked him to respond directly to you.

A.E. Holmes
Deputy Executive Director

Australian Medical Association
New South Wales Branch

21st January, 1992

Dear Dr Gorman,

Your recent letter concerning attendance by a representative of the AMA at a recent meeting of the Standards Association of Australia on Recreational Diving has been referred to me for response.

Dr Boland asked me to inform you that he noted your comments. However, it would appear that the appointment of Dr Ian Millar as the AMA representative to this particular Committee is a matter more for the Federal Office of the AMA and, as noted in the first paragraph of your letter, as you have obviously written to the Federal President there is no doubt that your very strong views in this matter have been noted in the appropriate quarters.

Laurie Pincott
Executive Director

South Australian Branch
Australian Medical Association Inc.

19th January, 1992

Dear Dr Gorman,

Thank you for your letter regarding assessment of medical fitness for recreational diving.

It would seem to me that there should have been some consultation between SPUMS and the AMA prior to the Standards Australia Meeting, and I am not sure why this did not occur. I think you would realise that from personal point of view and my knowledge of the field, I would be quite conscious of the argument that a special knowledge might be required for these examinations. There are certainly some similar precedents in other fields.

I will pursue this matter further and get in touch with you again.

Philip Harding
President

Australian Medical Association
Queensland Branch

2nd January, 1992

Dear Dr Gorman,

STANDARDS AUSTRALIA RECREATIONAL DIVING

I write on behalf of Dr Robertson in reply to your letter received on 23rd December, 1991.

You appear to infer that a medical practitioner is inadequately trained to examine persons who wish to undertake diving. This is disputed.

However, doctors are always trying to learn. I am sure that if your organisation was prepared to circulate general practitioners with guidelines on your standards, they would be pleased to receive the information.

A. Nicholson
State Director

Australian Medical Association Limited
ACT 2600
6th January, 1992

Dear Dr Gorman,

I am replying on behalf of the President and of the AMA to your recent letter, received here on December 23 last, in which you expressed dissatisfaction with the AMA's position on medical examinations for recreational scuba diving. Your letter underestimated the consideration which the AMA has given to this matter.

The AMA is bound by its Articles of Association to advocate proven public health measures (this should be seen as including appropriate preventive measures) and to promote the interests of its members and of the broader medical profession. When any conflict between these objectives is apparent, the AMA takes counsel so as to resolve such dilemmas appropriately.

The Section of General Practice of the AMA's Queensland Branch first brought to notice a proposal that "recognised training" should required for doctors completing fitness examinations for recreational scuba divers. The Queensland Branch opposed such moves because of the perception that they were unnecessary, because of their likely impact on GP members in a State where scuba diving is so prevalent, and because of the anticipated expense involved for members obtaining such training when they would perform relevant examinations infrequently. I informed myself of SPUMS' views through correspondence with our colleague Carl Edmonds, who took exactly the view you expressed in your letter. Indeed, I had much personal sympathy with SPUMS' approach: during 20 years RAAF service, I had considerable, albeit peripheral, contact with SPUMS and with hyperbaric practitioners. I have visited and observed hyperbaric operations at HMAS Stirling, the former HMAS Leeuwin, also participated in evaluation for airworthiness of a Koch's mobile recompression chamber at HMAS Penguin, etc. I spent a number of years in the Institute and underwent familiarisation training in hyperbaric medicine at the USAF School of Aerospace Medicine. I have numerous friends in the hyperbaric medicine community and I believe I am well acquainted with the background to SPUMS' concern.

That said, I am equally aware of the concerns of our GP membership who see the scope of their practice almost daily further circumscribed. I found the precedent that CAA has not until now required designated medical examiners for aviation licences, particularly in the lower grades, to undertake specified training (although it recently foreshadowed its intention to do so in future) persuasive in favour of the GPs' view. After further discussion with our colleague Ian Millar, he and I mutually agreed that the AMA should oppose any immediate requirement for diving medical examiners to undertake specified "approve" training. However, he and I both agreed that the completion of an appropriate training course should be seen as an appropriate mid-term goal, perhaps over the next five years, provided that training courses are made more accessible to doctors who wish to undertake them. For many of our GP members, course fees are a lesser consideration than travel and accommodation expenses incurred in attending courses remote from their practices, the difficulty of obtaining suitable loca tenentes, and so on.

The AMA wishes only cordial relations with SPUMS and similar professional bodies. Regrettably, on questions such as medical examinations for recreational scuba divers, where there is no professional consensus, it is impossible for the Association to please all participants in the debate.

P.S. Wilkins
Assistant Secretary General (Health Services)

It is of interest that one State considered that there was some validity in the SPUMS view, while two were happy to leave matters to the Federal AMA and one exhibited the 19th century attitude that after graduation every doctor knew everything. The letter from the Federal AMA was most interesting as the writer obviously agreed with the SPUMS position but was forced to opposed it because of Queensland GP opposition to the suggestion, well founded though it was, that the necessary knowledge was missing.

It is of great concern to the Committee of SPUMS that the AMA, often erroneously referred to as the Doctors' Trade Union, is putting the financial interests of some of its members before the good of all our patients. The comparison with pilots' medicals is flawed because these have been restricted, for over 30 years, to a list of approved doctors, which is what SPUMS is asking for diving medicals. That only in the last few years has the relevant government body decided that it may be necessary to require training in aviation medicine to be on the list shows that SPUMS has more interest in the safety of divers than the government has had in the safety of pilots and their passengers.

We need to get the AMA to move with the times and uphold the good name of medicine and its ideals of putting the patient first. I want SPUMS members and associates to write to the Federal AMA and their State branch. Ask the AMA to put patients first and support the SPUMS view that diving medicals should be done by doctors with training in underwater medicine. A simple way of doing this would be to photocopy this article, add your name and address and send it off.

John Knight
Editor, SPUMS Journal
SPUMS representative to Standards Australia

Reference

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

RESORT SCUBA COURSES IN QUEENSLAND: NUMBERS AND COSTS

Jeffrey Wilks

Background

Each year thousands of people have their first scuba diving experience on the Great Barrier Reef. Introductory or resort scuba courses are easy to conduct and are generally very satisfying for both the customer and the instructor. Resort divers say they expect to see coral and fish on their first dive, and later report that they particularly enjoyed the colour and beauty observed underwater. Some, or it may be many, follow up their initial scuba experience with a formal open water course to become certified divers.

While resort courses are generally safe, by virtue of students being closely supervised at all times by a certified instructor, some legitimate concerns have been raised about the current method of determining students' fitness to dive. Concern about variability in teaching standards have recently been addressed by PADI (Professional Association of Diving Instructors) through the introduction of a standardized instructional system for resort programs. It is hoped that this will help solve the problems.

However, any objective discussion about resort courses is still hampered by a general lack of empirical data. For example, the number of resort dives conducted in Queensland each year is not known, and only one small study has examined customer perceptions of their introductory diving experience. There is also no reliable data on the morbidity or mortality of the resort course.

Instructors are the critical factor how resort courses are conducted. In order to discuss resort programs it is first necessary to gather some basic information about these courses. The present study sought this information form the people who provide the service.

Methods

Two hundred and two registered Queensland scuba instructors, representing all four Australian training agencies, participated in the study. NAUI (National Association of Underwater Instructors) members were recruited through a direct mail-out from Australian headquarters, along with a letter of the organisation's support for the project. PADI, SSI (Scuba Schools International) and NASDS (National Association of Scuba Diving Schools) instructors were recruited through personal visits to retail shops, phone calls and informal networking. The final sample contained full-time (57%) and part-time (43%) instructors. The various employment categories were, owners and managers (27%), salaried staff (39%), and independent instructors (34%). Figures from the training agencies indicate that there were 616 certified instructors in Queensland at the time of this study, so the sample represents 33% of Queensland instructors.

All instructors completed a 16-page confidential questionnaire covering a range of topics related to their work in the dive industry. Instructors were asked if they ran introductory or resort courses as part of their current job. Those who did run these courses were asked to report on approximately how many students they personally supervised in the past 12 months, and also the price they charged for a resort course. Finally, instructors were asked if the courses they ran included a separate pool training session.

Results

One hundred and forty six instructors (72% of the sample) reported that they conducted introductory or resort course scuba programs. Table 1 show the number of resort students personally supervised by the instructors in the past 12 months. Seventy two, almost half the sample (49%), supervised less than 50 resort students in the year. Twenty two instructors (15%) supervised 50-100 students, 17 (12%) supervised 101-120 students and 20 (14%) supervised more than 500 students a year. One instructor commented that he had supervised (and logged) more than 1,000 resort dives in the previous year.

TABLE 1

NUMBER OF RESORT COURSE DIVERS

Divers supervised	Number of instructors	%	Mid-point	Student totals
Less than 50	72	49	25	1,800
50-100	22	15	75	1,650
101-200	17	12	150	2,550
201-300	6	4	250	1,500
301-400	6	4	350	2,100
401-500	3	2	450	1,350
More than 500	20	14	600	12,000
	146			22,950

Table 1 also indicates the mid-point number to best represent the average number of students each instructors supervised. While some specific detail was lost in using categories, pilot studies had shown that asking instructors to report exact numbers would pose difficulties. Based on the mid-point, and the number of instructors reporting students at each level, the final column in Table 1 shows the likely student totals. Together these instructors provided a resort scuba experience for an estimated 22,950 students.

Table 2 shows the cost of the courses conducted and the number and percentage of instructors who reported charging the corresponding price at each level. Costs raged from $20 to $ 265, the average (mean) price for a resort course in Queensland was $67. The mode (most frequently reported price) was $60. Almost two-thirds (62%) of the resort courses included a separate pool training session.

Using the estimated total of 22,950 students total revenue generated from these students was $1,414,950.00. This figure is the product of student numbers (mid-point) by course cost, calculated for each instructor separately, then summed for the full sample. Pro-rata, this figure suggests that approximately $ 4.2 million is generated by resort courses each year in the State. A current industry study, still in progress, tends to support these figures. Based on 80 Queensland companies supplying their figures for 1991 a total of 65,000 resort dives have been recorded. At an average price of $60 per dive this represents a revenue of $3.9 million. Several large companies specialising in resort courses have still to submit their returns so the above figure of $4.2 million is considered to be reasonably accurate.

TABLE 2

COST OF RESORT COURSES

Cost	Number of instructors	%
< $25	5	3
$25-30	20	14
$31-40	14	10
$41-50	30	21
$51-60	31	21
$61-70	4	3
$71-80	14	10
$81-90	4	3
$91-100	7	5
$100-150	10	7
> $150	7	5

The present study shows that, in financial terms, resort courses contribute substantially to the Queensland recreational diving industry. From the only other empirical study available, resort divers report a high level of satisfaction with their introductory scuba experience. Although resort courses are considered safe, there is little reliable data on accidents that have occurred. Accident data needs to be made available so that steps can be taken to avoid problems in the future. The quality of service being offered also remains to be investigated. With so many people taking their first resort dive each year the industry needs to guarantee that the experience will be safe and enjoyable.

Acknowledgements

This study was supported, in part, by a research grant from the Key Centre in Strategic Management, Queensland University of Technology. Special thanks are extended to those instructors, from all four training agencies, who participated in the project.

Dr Jeffrey Wilks, PhD, is a Psychologist and Tourism Research Fellow, Key Centre in Strategic Management, Queensland University of Technology, GPO Box 2434, Brisbane, Queensland 4001, Australia.

SPUMS NOTICES

CHANGE OF ADDRESS

The Australasian College of Occupational Medicine (ACOM) has decided to become a Faculty of the Royal Australasian College of Physicians and will not be able to provide a permanent mailing address for SPUMS beyond December 1992.

The Council of the Australian and New Zealand College of Anaesthetists (ANZCA) has kindly consented to provide SPUMS with a permanent address.

All correspondence, **addressed to the office holder concerned**, should be sent to

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

CONSTITUTIONAL AMENDMENT.

At the 1992 Annual General Meeting it was agreed to change the financial year to January to December. The Society had been using a Financial year that ended on 30th April. However the Rules of the Society contain the definition *"Financial year" means the year ending 30th June.*

In order to abide within the Rules this definition will have to be changed. It is proposed to put the following resolution to the 1993 Annual General Meeting.

That the words "30th June" appearing in rule 2 (a) be changed to "31st December".

Darrell Wallner
Secretary of SPUMS

MINUTES OF THE SPUMS EXECUTIVE COMMITTEE TELECONFERENCE

held on 30.8.92 at 1000 EST

Apologies

Drs A Slark and J Williamson.

Present

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

1 Minutes of the previous meeting

The minutes of the meetings on 31.5.92 and 1.6.92 were accepted as a true record. Proposed by J Knight, seconded by D Wallner.

2 Business arising from the Minutes

2.1 Palau ASM

Date 16.5.93 for 10 days. The entire hotel has been provisionally booked and both diving operators have been booked. Allways Travel will be sending out a brochure soon.

2.2 PNG ASM

Dr Acott will be carrying out a site inspection in November. He thought that the meeting should be held in Rabaul. This would mean that diving will have to be carefully supervised and probably that divers will have to be categorised as to the suitability to dive certain sites. Malarial prophylaxis will be a necessity. Dr Acott suggested a combination of Doxicyclin and Chloroquin. Lariam is not recommended because of side effects including spatial disorientation, giddiness, aches and pains. An antimalarial regime will be advised with bookings.

2.3. Other ASM sites

Dr Gorman will be making a trip to the Red Sea and will investigate the possibility of holding an AGM there.

2.4 Quotes for future ASMs

Dr Paton cannot expect to get firm quotes for meetings three yeas in the future. She will undertake preliminary discussions with other operators and obtain expressions of interest.

3 North American Chapter

Reimbursement has occurred. Dr Knight has forwarded Journals to Steve Dent for posting in the USA. However no indication that they were received nor of the cost of postage has arrived. Dr Knight will contact Ray Rogers by fax.

4 Diving doctors list

This is nearly complete. Many subscription forms, with the Yes ticked, have had to be checked for qualifications.

The Australian Sports Medicine Federation ran an accredited course in Western Australia during 1986. Dr Davies undertook to forward a list of the successful candidates to the Secretary.

Dr Gorman has had discussions with NASDS about insulin dependant diabetics diving. He emphasised their unsuitability to be passed fit to dive.

5 Treasurer's report

Approximately $ 30,000 in renewal subscriptions has been banked and all debts paid. Accounts in Dr Barry's name have been closed or transferred to Dr Paton. Dr Wallner is authorised to sign cheques as well as Dr Paton.

The problem of members who have paid in US$ was discussed. It was decided to credit them with the excess payment against their next subscription.

Subscription reminders will be sent out soon.

6 Permanent address

The Australian and New Zealand College of Anaesthetists has consented to provide a permanent address for SPUMS. The change will be advised in the next two Journals. Subscription renewals will be returned to the Treasurer, C/o Australian and New Zealand College of Anaesthetists, Spring Street, Melbourne, Victoria 3000. They will be forwarded direct to Dr Paton.

7 Duties of Convener

7.1 It was again agreed that all papers top be given at ASMs must be given to the Convener before the meeting.

7.2 A breakdown of the costs to be covered by the Registration Fee must be provided by the travel agent and approved by the Convener before the brochures are sent out. The difficulties that Dr Williamson had in trying to obtain these figures of the 1992 ASM were noted.

8 Hyperbaric paramedical staff

The status of this group was discussed. The SPUMS constitution precludes such people being granted full membership, but they are welcome as associates. Paramedical staff have their own organisation, the Hyperbaric Technicians and Nurses Association (HTNA). The ANZHMG is a SPUMS standing committee and can present HTNA opinions to the SPUMS Executive.

9 Diving First Aid bag

Dr Williamson agreed to review the equipment regularly and to arrange its transport to the various venues. It was agreed to remove the in-water oxygen equipment from the case. The provision of and means for administering oxygen will be the responsibility of the Convener for each ASM.

10 Secretarial duties

The work load was discussed and a change may be necessary later.

11 Journal costs

Dr Knight will obtain quotes from printers in Melbourne. The advantage of using a printer near the Editor may outweigh the lower quotes using printers in the ACT.

12 Correspondence

12.1 Dr Mark's' paper will appear in the Journal, as agreed at the last meeting, as the Editor has not heard from Dr Mark that that it has been accepted by the Medical Journal of Australia.

12.2 Dr R Thomas' letter and the PADI/Dr D Walker correspondence was discussed. It was decided that a carefully balanced Editorial will be written by the President and published in the Journal on diving safety and the relationship between SPUMS and the diving instructor organisations.

12.3 Letters from the AMA were discussed. It was agreed that no further action should be taken.

12.4 Worksafe Australia

Thee composition, and particularly the lack of expertise of some members of the Occupational Diving Expert Group was criticised. Dr Gorman's letter will be circulated. Dr Knight stated that Worksafe Australia was merely rehashing AS 2299 in indecent haste.

13 Free Ascent Training

13.1 The committee is not agreed on whether free ascent training should be carried out as part of basic training. Those with naval training consider that it should not be carried out. Dr Acott drew attention to the lack of hard data.

It was decided to hold a Workshop to discuss the problems for free ascent at the 1993 ASM. Letters will be sent to UHMS and diving organisations notifying them of the Workshop.

13.2 Diving Club membership

It was agreed that diving clubs should be associate members. Libraries and bodies intending to make a profit from diving should be corporate members.

13.3 BS-AC medical statements

It was agreed that the concept is a good one. It was suggested that SPUMS might produce its versions of the more debatable topics.

14 Next Meeting

To be on 15.11.92 at 1000 Eastern Summer Time.

MEETINGS

SPUMS ANNUAL SCIENTIFIC MEETING 1993
will be held at
the Palau Pacific Resort
SUNDAY 16TH TO TUESDAY 25TH MAY 1993

The guest speaker will be Professor David Elliott, co-author of The Physiology and Medicine of Diving with Dr

Peter Bennett. He is an excellent teacher and entertaining speaker. The theme of the conference will be

THE LONG TERM EFFECTS OF DIVING

A workshop on

FREE ASCENT TRAINING

will be part of the program

Anyone wishing to present papers should contact the Convener, Dr Des Gorman, at the RNZN Hyperbaric Unit, Naval Base, Devonport, New Zealand.

Those who wish to attend should notify Allways Travel, with a deposit of $Aust 600 per person.

For further information contact

Allways Travel
168 High Street, Ashburton,
Victoria 3147, Australia.

Telephone	Australia	03 885 63
	International	61-3-885 8863
	Toll Free (Australia only)	008 338 239
Fax	Australia	03-885 1164
	International	61-3-885 1164

FIRST ANNUAL SCIENTIFIC MEETING OF DIVING AND HYPERBARIC MEDICINE

will be held in Darwin, Northern Territory, Australia on July 29th and 30th 1993.

The meeting is sponsored by the Hyperbaric Technicians and Nurses Association (HTNA) and the Australian and New Zealand Hyperbaric Medicine Group (ANZHMG). The AGMs of both associations will be held on July 31st.

The main topics will include, but are not limited to, wound healing, decompression illnesses, hyperbaric treatment profiles, recreational nitrox diving, new technical developments and current hyperbaric research.

CALL FOR ABSTRACTS

Those wishing to present papers should forward abstracts of approximately 200 words by February 1st 1993 to

Ms Jodie Perris
Royal Darwin Hospital Hyperbaric Unit,
Rocklands Drive,
Tiwi,
Northern Territory 0810, Australia.

Further information and registration details will be mailed to all HTNA and ANZHMG members. Non-members can contact Ms Perris at the above address or by telephone (089 22 8563).

THE SPARK OF LIFE

Cardiopulmonary Resuscitation and Emergency Life Support Conference
The Hilton International, Melbourne, Australia.
April 30th and May 1st 1993

Provisional program, abstract and registration forms available from

The Australian Resuscitation Council
Royal Australasian College of Surgeons
Spring Street, Melbourne,
Victoria 3000, Australia.

LETTERS TO THE EDITOR

SPUMS JOURNAL - FOR DOCTORS OR DIVERS?

RMB 1359, Yinnar
Victoria 3869
18 October 1992

Dear Editor,

I have for the last several editions debated whether to put pen to paper regarding what I considered to be an unfortunate direction of the SPUMS Journal was taking.

I decided against on each occasion feeling that perhaps I was out of touch with where the diving industry was heading. I contemplated withdrawing my associate membership of SPUMS in silent protest. To my great pleasure I find in the latest edition that Dr Carl Edmonds has verbalized most of my concerns. Well done Dr Edmonds, I couldn't have have put it better myself.

I have been instructing for some 15 or more years and continue to do so. I belong to an instructor agency out of necessity rather than because I want to. I do not accept the direction that the instructor agencies are leading us in the name of commercialism and business. I lament the reduced independence of the individual professional instructor that results from this agency thrust and the continual erosion of the basic scuba course.

I believe that the SPUMS Journal is for doctors and divers, but not agencies, nor it is a vector for unrefereed propaganda material such as has appeared recently. The journal should dedicate itself to diving medicine, physiology and an on-going analysis of diving accidents. The less rigorous unscientific material should be left for the lay diving press and agency propaganda documents.

A clear uncompromised voice with no vested interest other than the safe conduct of diving for the individual divers sake is to be encouraged. Divers should be encouraged to dive together to enjoy the splendours of the undersea world safely. They should not be considered the property of the agency that trained them nor should the training agencies let business ideals interfere in any way with diver safety.

Peter Mosse

Irish Underwater Council
The National Maritime Museum
Haigh Terrace, Dun Laoghaire
County Dublin
October 1992

Dear Editor,

I have been an associate member of SPUMS for the past 8 years and think that the Journal is an extremely good publication. Your medical authors provide very useful and up to date diving medical facts and information.

Over the past years I have been surprised that you have allowed PADI to publish so many of its propaganda articles in the Journal, then I thought SPUMS was, in its own way, supporting the ideas expressed in these articles, despite adding editorial comment to some articles.

I was surprised to read Dr Gorman's editorial and Dr Carl Edmonds' letter expressing your dissatisfaction about these training agencies' articles . I agree completely with Dr Edmonds' sentiments regarding these financially orientated organizations. I would have thought that SPUMS expressed a medical opinion based on experience and knowledge and it is up to us, the divers, to accept or reject it. I would be very disappointed if SPUMS altered their point of view to facilitate a commercial organisation.

In Ireland we have annual medicals for all sports divers and you would be surprised at the number of people who are screened out. Well I am sure you know what I am talking about. We have some people who falsify the medical forms, but generally they get caught out. As a result we have a small but healthy population of divers.

I can see why training agencies do not advocate medical check ups. It would probably reduce their intake by 20% at least, so they allow the prospective client to accept all the risk by filling in their own medical form without fully understanding the implications for their safety. Then to add to the ridiculous, a non-medical person, the instructor, assesses the medical questionnaire and the acceptability of the candidate. I presume they reckon that candidates will be with them for such a short time and with careful watching they will get through the course without any mishap. What happens after is not their problem. The candidate goes away thinking he, or she, is physically fit and has sufficient knowledge to go diving on their own which is debatable. This is my biggest objection to these agencies, their lack of proper "after care".

SPUMS should hold its ground and state the medical facts, regardless of what other agencies think. It is up to us (the diving community) to make up our own minds. You state that PADI puts through its courses more people than all the rest of the training agencies combined, this may be so. However, does it make them right in everything they say or do. It simply means that this is the best way to present information so that they can make more money. I find it very interesting that PADI tries so hard to get recognition from SPUMS for almost everything they do. I think that articles presented from any training agency should not be written in a propaganda fashion

As you may be aware, PADI are trying to get back into CMAS. They say they do not need the support of CMAS or SPUMS or such organisations, then why do they bother to try to get recognition from them!

I could go on and on. But I will finish now and just say I have no objection to the function of training agencies, i.e. to train divers. I do object though, to their propaganda and the fact that they try to infiltrate every prestigious diving organisation in order to use them to their advantage.

Gerry Stokes
Vice-President
Irish Underwater Council

Hyperbaric Technicians and Nurses Association
Hyperbaric Medicine Unit, Royal Adelaide Hospital
North Terrace, Adelaide, South Australia 5000

September 1992

Dear Editor,

The Hyperbaric Technicians and Nurses Association (HTNA) held its first AGM in Adelaide on the 28th and 29th August, 1992. As well as being attended by nurses and technicians from all the hospital based hyperbaric units in the country, there were also personnel from private hyperbaric facilities, the Royal Australian Navy, the SA Police force and the commercial diving sector.

The Association aims to promote and encourage the exchange of information between members, to standardise protocols and practice within technical and nursing communities affiliated with the HTNA, to educate and inform the recreational diving community of developments that affect safe diving practices and to standardise training requirements for hospital based hyperbaric technicians.

During this meeting it was agreed that the HTNA should maintain close ties with both SPUMS and ANZHMG.

Our full membership is open to nurses and technicians currently working in the field of hyperbaric medicine, and associate membership is open to other interested parties.

Application forms for the HTNA are available from Steve Goble, Hyperbaric Medicine Unit, Royal Adelaide Hospital, North Terrace, Adelaide, South Australia, 5000.

Steve Goble
Hyperbaric Technicians and Nurses Association

BOOK REVIEWS

DIVING MEDICINE FOR SCUBA DIVERS
Carl Edmonds, Bart McKenzie and Robert Thomas.
J.L.Publications, PO Box 381, Carnegie, Victoria 3163, Australia.
ISBN 0 9590306 62
RRP $A 34.00

This book is not just a guide to diving medicine in non-medical language. It fills that role but it does much more. Besides explaining the physics and physiology and medicine of diving in language that is simple to understand the text is laced with humour and full of illustrations. Some of the cartoons used to illustrate statements are unforgetable! It is fair to say that this is the most complete coverage of diving medicine in non-technical language that has ever been available.

However it may not meet with approval from some of the diving instructional agencies as it is peppered with advice on how to dive safely and avoid the common causes of diving injuries. It is quite clear that the authors, who have had almost thirty years of full time diving medicine between them and a much longer exposure to diving themselves, consider that diving is a dangerous sport which can be undertaken safely if the diver knows enough and has had good training and has practiced the required skills regularly. They draw attention to the lessons to be learnt from studies of diving deaths, most of which occur in the inexperienced. They draw attention to the fact that decompression illnesses occur in divers who dive within the tables, but occurs more often in those who stray outside the table envelopes. They consider that dive computers still have a long way to go to improve their safety.

The book is divided into five sections. These are Background which includes a potted history of diving, Specific Diving (pressure related) Diseases, Aquatic Diseases, General Diving Medical Problems and finally Treatment and Prevention. There are five appendices covering a diving medical library, emergency contact numbers (with space for the owner to add his or her own local numbers), the DCIEM tables in full, the USN tables and the protocol for in-water oxygen recompression therapy.

In its 1.5 cm thickness is information that covers everything a non-medical recreational scuba diver might want to know about diving. That is not to say that the information in encyclopaedic on every topic, but the basic and essential facts are always mentioned.

Unfortunately in the review copy a couple of pages have been printed with a letter or two missing from one side of the page. Luckily the meaning can easily be deduced from the context.

The authors claim that the SPUMS Journal appears six times a year which I hasten to add is wishful thinking. It is hard enough to combine an anaesthetic practice and production of a quarterly Journal. Unfortunately the address of SPUMS and of the Journal has changed since the book went to the printers.

It is not just a trimmed down version of Diving and Subaquatic Medicine, it is a new book aimed at the ordinary diver. It is an excellent display of the contribution that diving medicine can make, and has made, to diving safety. A "free" copy should be included in the price of every diving course in all English speaking countries.

John Knight

MEDICAL WRITING: A PRESCRIPTION FOR CLARITY.
Goodman NW and Edwards MB.
Cambridge: Cambridge University Press, 1991.
ISBN 0-521-40701-X.
Pp 190; RRP £14.90 overseas (includes postage).

Clifford Allbutt wrote *Notes on the Composition of Scientific Papers* in 1904 because the MD theses he had to examine were so poorly written. Improvement since seems to have been non-existent; in 1991 Goodman and Edwards report that "medical writing in English is often bad to the point of dreadful." Unfortunately, on past showing their excellent contribution to a growing body of instruction seems unlikely to be read by those who most need it, the many complacent and apparently illiterate doctors. Which is a pity because the present guide is unstuffily written, readily digested, and replete with examples of bad (in bold type) and good English; there are also plenty of do it yourself exercises.

The message is that words should be used with the utmost care. They need to be clear, precise, short if possible, "give" rather than "administer", concrete rather than abstract, free from jargon and felicitous. Anyone who uses "prior to", for example, should be advised against writing. Superfluous phrases like "The evidence suggests that" and dangling participles "Having admitted the patient the abdomen was examined" should be avoided. Pick any sentence in the book: "This comprises of increased blood pressure and pulse amplitude in the upper extremity and decreased blood pressure and pulse amplitude in the legs." If you cannot improve on it your writing needs urgent treatment.

Alex Paton

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The book is available from the BMJ Bookshop, PO Box 295, London WC1H 9TE, UK. Payment can be by credit card (Mastercard, Visa or American Express) stating the card number, expiry date and full name.

OXYGEN FIRST AID FOR DIVERS.
ISBN 0-9590306-5-4
John Lippmann
J.L.Publications
P.O.Box 381, Carnegie,
Victoria 3163, Australia
RPP $A 20.00

There are many courses available throughout Australia which teach the administration of oxygen in association with advanced first aid. Until the advent of this book, there has been no textbook to which these students could readily refer. Previous discussion of the subject has usually been directed at a medical audience which has made the subject very difficult to read for the lay person. This new book by John Lippmann will fill this void very nicely. Although it is primarily directed at the diving community, the book will be widely read by all teachers and students of advanced first aid in Australia.

It has long been taught, especially by the medical community, that the administration of oxygen to a casualty is potentially hazardous so that the whole subject has become clouded with mysticism. John Lippmann's very comprehensive monograph will be instrumental in eliminating the misconceptions and fallacies that have arisen and allow the whole subject to become much clearer.

The author has taken considerable pains to keep the language simple and to avoid much of the medical jargon that complicates similar texts. He has thoughtfully included a glossary of medical terms and their definitions towards the end. The medical reader may become annoyed by some of the circumlocution but I feel this is necessary for the layman to understand some of the concepts that we take for granted.

The *dramatis personae* of the editorial panel reads like the Who's Who of Australian diving medicine and these worthies have ensured that the author has been given the very best advice on both techniques and equipment. His description of the equipment available, its merits and defects, is exhaustive and will enable any club committee to make a valued judgement on which piece of apparatus to purchase for their use.

Because the book is designed to complement any advanced first aid course, the chapters follow in logical sequence from the anatomy and physiology of respiration through the types of oxygen administration systems and the techniques of their use on to the complications and even the lethal implications of failed first aid.

The whole book is well illustrated with photographs and diagrams although the quality of reproduction is lacking and some of the photographs are unclear and their impact is lost. In his description of the C.I.G. variable flowmeter, Fig.8.13, the author omits to mention that for accurate measurement, it is essential that the glass tube be held vertically to allow the ball to be suspended in the middle of the tube. With the tube lying flat as it is pictured, and as I have seen in even the best regulated circles, the position of the ball gives no indication of the actual flow rate. Other bourdon-type gauges, as illustrated in Fig. 8.14, do not suffer from this problem of position, are usually more robust and less likely to suffer injury while being moved on and off a dive boat.

This book joins the list of first class publications from this author and like The DES (DAN) Emergency Handbook, it will become an essential part of all diving first aid kits. It is simply written and very easy to read by anyone with a basic knowledge of first aid and resuscitation. For overseas readers it may not describe the equipment available in their area, but the techniques of resuscitation and principles of administration of oxygen to a diving casualty are universally applicable. I commend the author for his effort in producing this very valuable addition to the library of diving medical publications.

David Davies
Education Officer, SPUMS

SPUMS ANNUAL SCIENTIFIC MEETING 1990

SCUBA DIVING INCIDENT REPORTING THE FIRST 125 INCIDENT REPORTS

Chris Acott

Introduction

Errors ("performances which deviate from ideal")[1] are a part of our everyday existence.[2] The majority of these errors are usually trivial, of no significance, recurring and preventable.

Accidents are errors "with sad consequences"[3] and occur in a system which is "tightly coupled"[3] and so not forgiving. Research in aviation, the nuclear power industry and maritime transport accidents has shown that accidents are rarely produced by a single cause but usually by a host of interacting ones. Accidents are, therefore, the consequence of a group of errors, or a collection of interacting negative incidents.

Incident reporting

Incident reporting involves the study, reporting and analysis of error. When applied to human performance it deals with human error.[2,4-7] It examines the contributing factors and associated patterns.[4,5] These factors and patterns have received little attention in accident reporting,[1-3] and their elimination will ultimately reduce error[2] (see Figure 1).

Corrective strategies are designed to eliminate these contributing factors and associated patterns.

Incident reporting involves several steps:

1 Recognition: realizing that an incident, although thought to be trivial, has occurred, and that it may have some important implications.
2 Reporting: writing down the story of the incident and sending to the collector. This is helped by using a standard form.
3 Collection: there must be a focus point to which the reports are sent.
4 Analysis: patterns and factors in the reports must be identified.
5 Formation: corrective strategies are formed aimed at the elimination of the patterns and factors identified by analysis.
6 Feedback: the information is widely distributed in the community for utilisation.

In the 15 months from January 1989 to March 1990, 125 incidents were reported to the Diver Incident Monitoring Study (DIMS) which is based at the Hyperbaric Medical Unit, Royal Adelaide Hospital. Forty of these incidents (32%) were associated with morbidity.

Contributing factors

The common contributing factors for these incidents

FIGURE 1

THE COCK-UP CASCADE

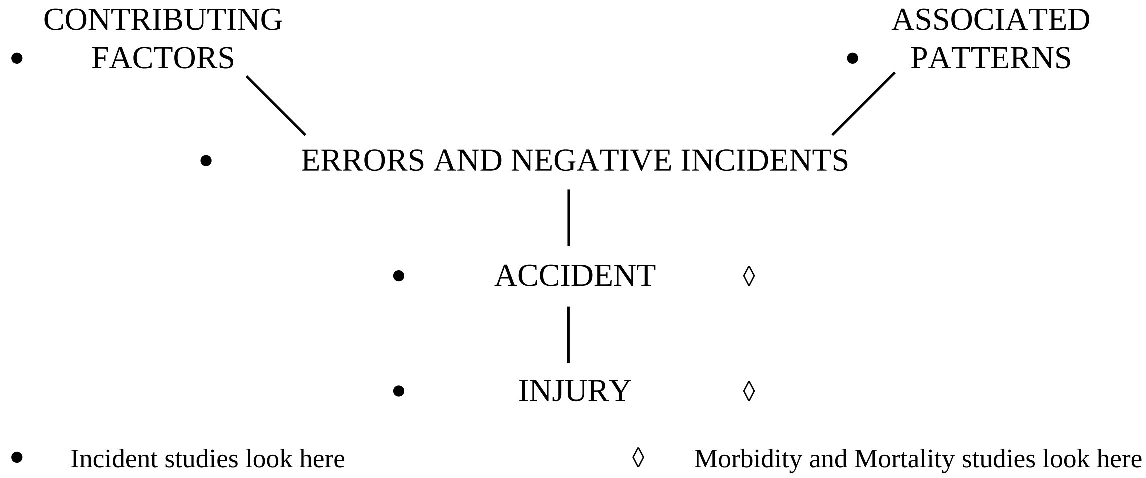
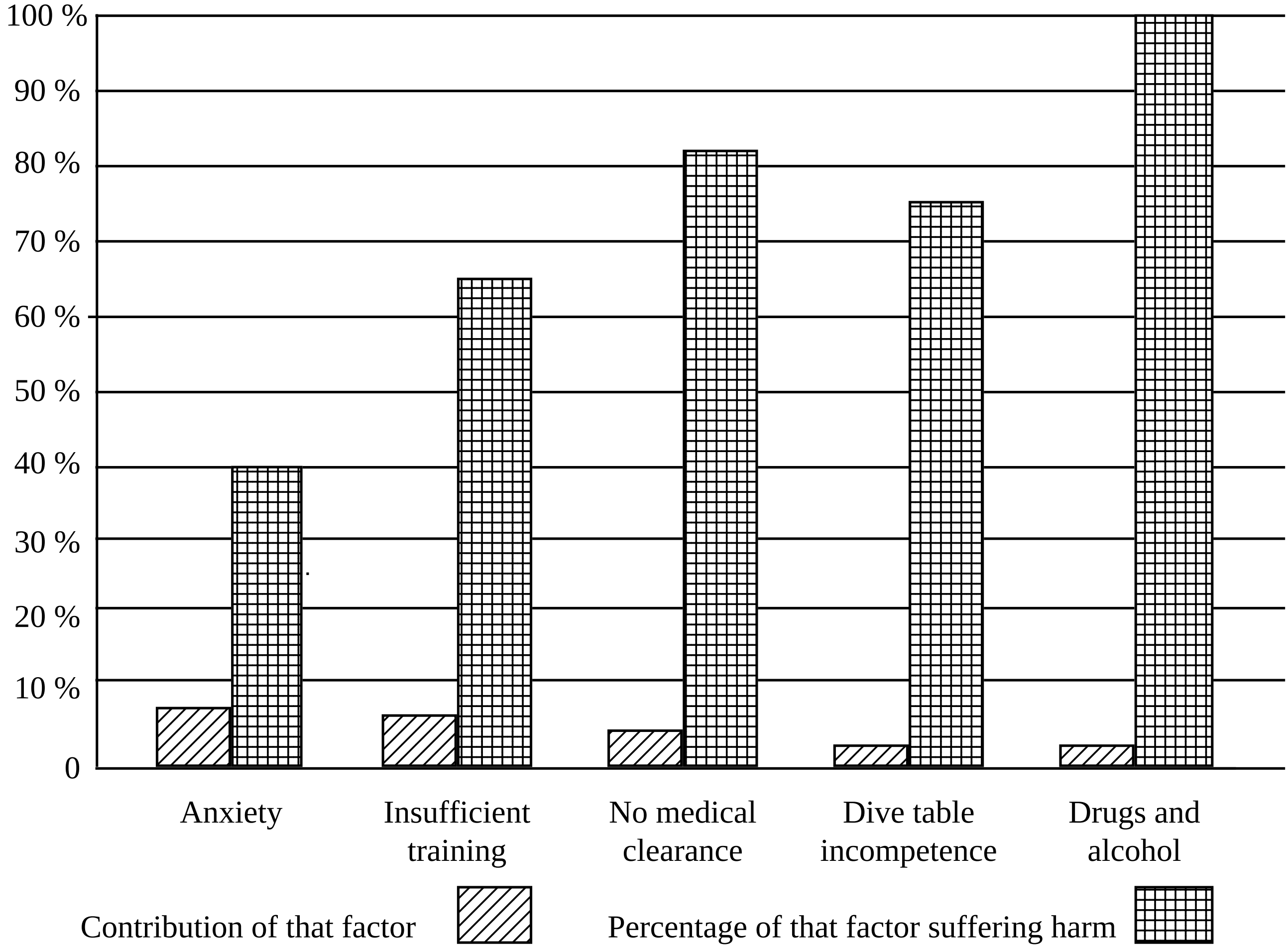


FIGURE 2

UNCOMMON CONTRIBUTING FACTORS LEADING TO HARM



were errors of judgement, poor dive planning, inexperience, inattention and diving in unfamiliar conditions

Morbidity

There were a number of less common contributing factors, anxiety, failure to understand the dive tables, drugs including alcohol, insufficient training and lack of a medical clearance, which when present were associated with diver harm. Table 1 shows to the associated morbidity.

In one diver, hospitalized for salt water aspiration, acute renal failure developed 48 hours later. The salt water aspiration caused a pneumonitis and right lower lobe collapse. No cause was found for his renal failure. He was treated conservatively and left hospital with normal renal function. He has since given up diving. The pulmonary infection followed breathing from a contaminated buoyancy jacket. Pseudomonas was cultured from the mouth piece.

TABLE 1

MORBIDITY REPORTED

DCS		14
Barotrauma		13
Ear	7	
Pulmonary	4	
Sinus	2	
Salt water aspiration		7
CAGE	4	
Coral sting		4
Right lower lobe collapse		1
Acute renal failure		1
Pulmonary infection		1

Cerebral arterial gas embolism (CAGE) was associated with two cases of salt water aspiration. However in this series, pulmonary barotrauma was not associated with detectable CAGE.

Experience and training

During training there were six incidents which resulted in harm. Equalization and shared breathing techniques predominated. One diver developed transient symptoms of CAGE after a swimming ascent but failed to report his symptoms to his instructor. His symptoms were no longer transient after his second dive.

Errors were not confined to the inexperienced diver. Table 2 shows an equal distribution between experienced and inexperienced divers.

Incident detection

The majority of the incidents (46%) were detected during the dive.

Distribution of incidents associated with morbidity

Thirty (75%) of the 40 harmful incidents were detected during ascent and following the dive (Figure 3). Any incident that was detected during the ascent or following the dive was associated with considerable morbidity (Figure 4).

It was fortunate that the problems associated with handling of weight belts at the exit were not associated with morbidity. The dropping of weights (and weight belts) when leaving the water can have disastrous consequences on those below.

In 13 of these incidents divers reported that the management of the situation would have been helped by an alternative air supply. Four of the shared breathing situation resulted in salt water aspiration. Five of the out of air situations involved an inaccurate contents gauge.

Equipment problems

The majority of the 67 equipment incidents involved either the diver's regulator or buoyancy jacket.

FIGURE 3

WHEN INCIDENTS WERE DETECTED

FIGURES ABOVE COLUMNS ARE THE TOTAL NUMBER OF INCIDENTS REPORTED IN THAT STAGE OF THE DIVE

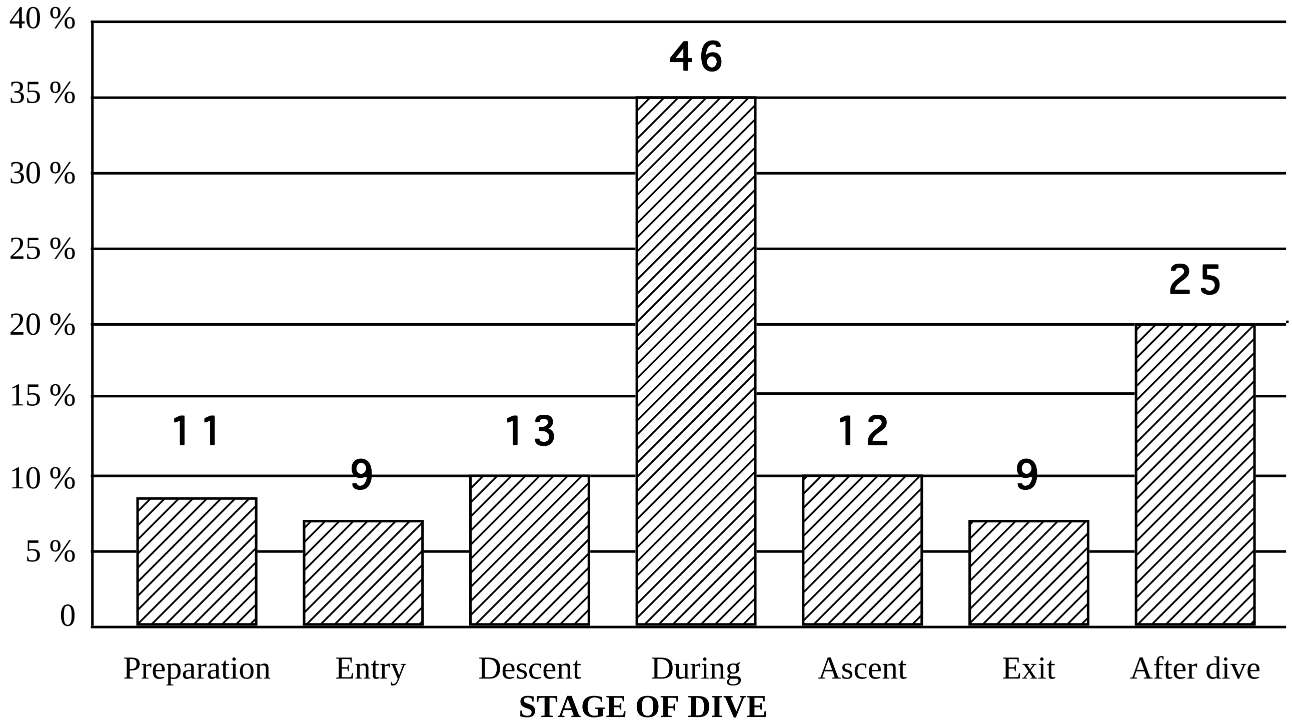


FIGURE 4

DISTRIBUTION OF INCIDENTS ASSOCIATED WITH HARM BY STAGE OF DIVE

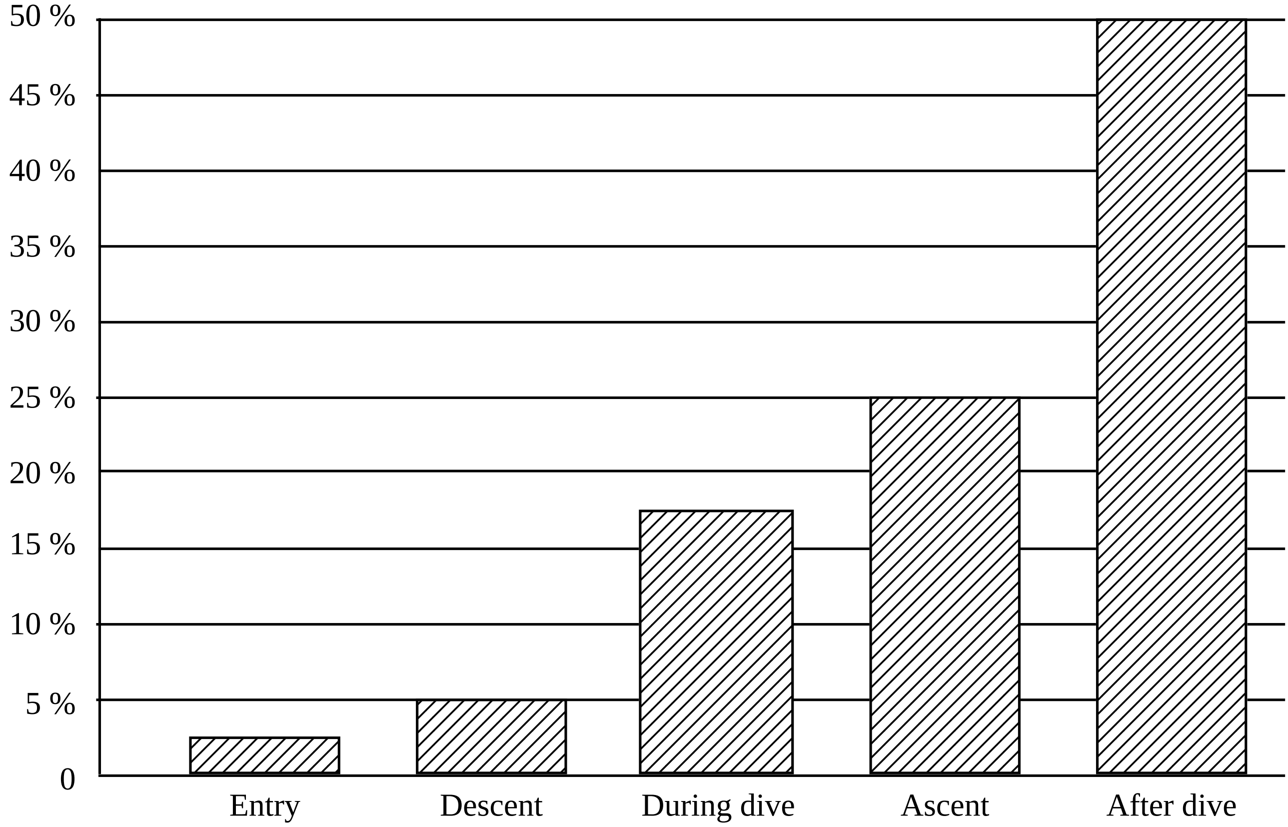


FIGURE 5

ALL INCIDENTS AND PERCENTAGE CAUSING HARM BY STAGE OF DIVE

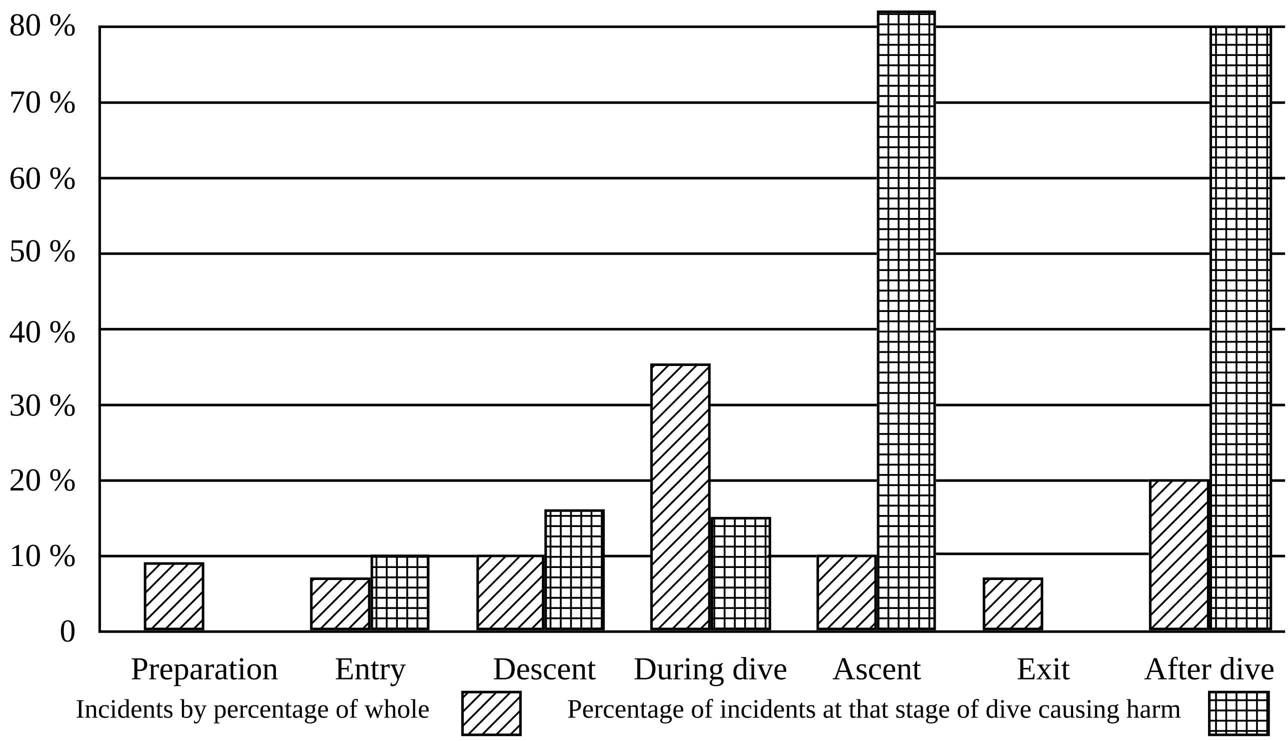


TABLE 2

EXPERIENCE LEVEL OF DIVERS INVOVLED IN INCIDENTS

Untrained	7
Under training	8
Basic	34
Open Water	37
Advanced	22
Dive instructor	11
Commercial	2
Unknown	14
Total	**135**

TABLE 6

AIR SUPPLY AND REGULATOR PROBLEMS

Inaccurate contents gauge	5
Free flowing 2nd stage	5
Misplacement of octopus	3
Rupture high pressure hose	3
Leaking high pressure hose	1
First stage blow out	1
2nd stage jammed	1

Equipment failures

Seventeen equipment problems did not involve diver error, and so could be considered as being pure equipment failure. Table 5 shows that pre-dive checks are not being executed, or if they are, they are brief and poorly conducted.

Oxygen equipment

In 5 incidents, where oxygen was available for the First Aid management, either the oxygen supply was inadequate or nobody was familiar on how to use the equipment. In all 5 incidents the concentration of oxygen achieved would have been far less than 100%.

TABLE 3

OUT-OF-AIR AND LOW AIR INCIDENTS

Out-of-air		9
Inacurate contents gauge	5	
Low air to out of air		5
Low air		4
Total		**18**
Coping strategies		
Octopus breathing		10
Water aspiration	3	
Buddy breathing		3
Water aspiration	1	
Direct ascent		6

TABLE 4

EQUIPMENT PROBLEMS

Regulator	19
Buoyancy compensator	18
Weight belt or weights	8
Wet suit	6
Fins	5
Air supply	5
Depth gauge	3
Mask	2

TABLE 5

BUOYANCY JACKET PROBLEMS

Unfamiliar with its use	4
Scuba feed not attached	4
Incorrect use	3
Tank not secured correctly	3
Unable to vent vest	2
Vest leaked	1
Inflation device failed	1

TABLE 7

EQUIPMENT PROBLEMS DETECTABLE BY BUDDY AND PRE-DIVE CHECKS

	Total problems	Detectable by buddy check	Detected by buddy check	Detectable by pre-dive check	Not detectable by pre-dive check
Regulator	19	14	1	14	5
Buoyancy compensator	18	15	1	11	2
Weight belt or weights	8	3	0	4	3
Wet suit	6	0	0	3	4
Fins	5	1	1	1	0
Air supply	5	5	1	5	0
Depth gauge	3	3	0	3	0
Mask	2	0	0	0	2
Dive computer	1	0	0	0	1

Discussion

Equipment problems predominate in this series of incidents. Misuse, misassembly, failure to check and lack of understanding of how the equipment functions all featured. Diving is an equipment dependent sport and a diver's interaction with his equipment is an important aspect of safety. The majority of the equipment problems related to buoyancy jackets and regulators.

This series shows 3 disturbing features.

1 A quarter of the regulator problems would not have been detected by any immediate pre dive check.

2 There was either an absence of or a poorly executed buddy check.

3 Inaccurate contents gauges were an important contributing factor in the out of air situations.

All the buoyancy jacket incidents were due to diver error. How to inflate and deflate the jacket, especially in emergency situations, and the correct function and use of the jacket do not appear to be well understood. Allied to this, correct weighting appears to be lacking, leading to uncontrolled or unplanned alterations in buoyancy, which can carry potentially serious consequences.

This study correlates well with other studies of human error by showing that the thorough checking of equipment ("check lists") before use is an important aspect of safety.[2,5,7] Pilots have a "cockpit drill", why not divers?

There has been little emphasis focussed on the accuracy of contents gauges in mortality reporting.[13] Once a gauge is sold it is seldom recalibrated or serviced. Inaccurate contents gauges were cited as an important cause of the "out-of-air situation". Reintroduction of the sonic reserve (the first stage regulator emits a noise with each breath when the cylinder pressure is low) could be an important safety measure. Irrespective of what the contents gauge shows the diver would know that he or she is low on air.

Sudden loss of air supply (due to first stage blow out or rupture of a high pressure hose) can have disastrous consequences. An independent alternative air supply would have made the management of these situations easier. But the alternative supply has to be an effective one, enabling the diver to get to the surface in all situations. An additional piece of equipment means more equipment to be checked before the dive, and this study has highlighted the lack of good pre-dive checking!

This study correlates well with other studies showing that alcohol increases the injury risk with aquatic sports.[8-10] Diving and alcohol do not mix!

Shared breathing techniques were a major cause of salt water aspiration. Poor technique when clearing the second stage caused problems leading to water being inhaled.

Understanding decompression table is pre-requisite for safe diving. Divers should be taught a set of tables thoroughly during training, and eligibility to dive should be based on their understanding of them and being able to work out the correct answers for single and repetitive dives. Knight[11] and later, Wilks and O'Hagan[12] showed that a high percentage of recreational divers lacked fundamental knowledge of decompression tables (even in a so called "well educated" group of divers).[11]

There is a correlation between the lack of medical fitness to dive and morbidity in this study.

The first aid management of diving accidents requires administration of 100% oxygen. Knowledge about how to achieve 100% oxygen and the equipment to use is lacking in the Australian diving community.

Divers should plan their exit from the water. Mishandling of weight belts at the exit may have disastrous consequences if another diver is underneath it.

Corrective strategies

DEVELOPMENT OF CHECK LISTS

Each diver should inspect and test their own and buddy's gear, especially inflation and deflation of the buoyancy compensator (BC), quick releases, air supply connections and safety devices. Each diver should carry a check list in his or her diving bag.

A check list should include the following:

BUOYANCY COMPENSATOR

1 Check the scuba feed is connected and will inflate and deflate.
2 Check the jacket for leaks when fully inflated.
3 Check oral inflation.
4 Check the emergency vent holes.
5 Check the tank is secure in the back pack.
6 Check that the buddy divers know where everything is located on both divers and are able to use them.

REGULATOR AND CONTENTS GAUGE

1 Switch air supply on. Note the full position on the contents gauge.
2 Switch air supply off.
3 Check the purge button (of both second stages if fitted with an octopus) works.
4 Note the "empty position".
5 Switch air supply on. Note full position again. Check that it correlates with No.1.
6 Check, with the air supply turned fully on, that the diver is able to breathe through both 2nd stages (if an octopus is fitted).
7 Check that breathing does not cause oscillation of the pressure gauge needle. If it does then the air supply should be checked to be certain that it is turned fully on.
8 Check that there is no positional free flowing of either second stage.
9 If the contents gauge is bumped before getting into the water, these checks should be performed again.
10 Check that the diver knows where his or her regulators are (especially the octopus).
11 Once in the water, do a surface check on any positional free flowing of the regulators.

SONIC RESERVE

Regulator manufacturers should be encouraged to reintroduce the sonic reserve and divers should be encouraged to buy this excellent safety device.

OXYGEN AND ADMINISTRATION

Australia wide standards for courses on oxygen therapy and equipment applicable to diving accidents should be developed.

ALTERNATIVE AIR SUPPLY

There are many alternative air sources available. They should have minimum standards of performance. The commonest is the octopus regulator. However this usually needed when both divers are low on air. In this situation the 1st stage regulator may not be able to provide enough flow to supply both regulators at once. Neither may it be able to supply enough air to inflate the owner's buoyancy compensator.

If a separate cylinder is used (Spare Air etc.) should this air source be able to supply the buoyancy jacket to give buoyancy as well?

TRAINING

There should be more emphasis in diving training on shared breathing and equalization techniques.

There should be better teaching and understanding of the dive tables.

Crisis management algorithms should be developed for the out-of-air situation, and for the First Aid management of diving accidents.

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He has been Secretary and President of SPUMS.

He is a Staff Anaesthetist at the Royal Adelaide Hospital. His address is the Hyperbaric Medicine Unit, Department of Anaesthesia and Intensive Care, Royal Adelaide Hospital, North Terrace, Adelaide, South Australia 5000.

SPUMS ANNUAL SCIENTIFIC MEETING 1991

EMERGENCY AIR SHARING

Glen Egstrom

Introduction

The purpose of this paper is to focus upon a positive approach to the standardisation of an important emergency procedure, sharing air. The behavioural aspect of this procedure could be effectively standardised with a minimum modification of equipment and existing techniques.

Why share air ?

Other than in training classes, one is normally only going to have to share air when one's buddy is out-of-air. It is a time of considerable stress. An out-of-air situation is most unlikely for a scuba diver who monitors his or her air supply. It can happen, but it is rare.

In many parts of the world regulators freeze. When gas expands it tends to cool. Air is expanding when it comes through the low pressure hose. We have tested a series of regulators at various temperatures and at various depths. Virtually all the regulators on the market will freeze up if they get cold enough and have enough air going through the regulator. Typically the regulator valve will stay in the open position, a free flow, and with free flow you get a tremendous cooling effect causing ice to form on the outside and on the inside of the regulator. Sometimes the regulator will freeze shut. This is a difficult and serious problem. In between sheet ice actually forms on the diaphragm increasing the breathing resistance. The increase in breathing resistance is enough to create additional stress as the diver may feel that he is out-of-air. Every regulator available is going to be more difficult to breathe from at low tank pressure and at depth.

A tropical diving holiday is probably the worst possible environment for a scuba diver. It takes about 72 hours to get about 80% acclimatised. Divers rarely have that long before they go to work enjoying themselves. Inspite of understanding the problem, we consistently let ourselves become dehydrated during the first two or three days. We are not sensitive to the need to push fluids when we arrive in the tropics. In addition we are offered deep, clear, warm water, party times and late nights. We are not as well prepared for some of our dives as we should be. As a result mistakes are made.

Many people who encounter increased breathing resistance interpret that as an out-of-air situation. It is important that people recognise that if one breathes slower and so keeps the peak flow rates low, then the resistance is going to be lower and one will be able to get air out of the tank comfortably for much longer. In most of the regulators on the market excessive breathing resistance starts about 500 or 600 psi tank pressure at depths of 20 m or more. Most of the good regulators on the market have different characteristics because the balanced first stages are so finely tuned that they will work up to a critical pressure and then fail to deliver. The diver has no warning, one breath has some change in breathing resistance and then one does not get the next breath, or if one does, one only gets part of it.

Out-of-air is a time for an emergency ascent. If one starts air sharing one should begin an emergency ascent. Emergency air sharing should not be done while one finishes the rest of the planned dive. That does happen. I know a diver who chooses young women as diving buddies because they do not use much air. When he gets tank his down to about 300 psi, he shares her tank until it is nearly empty. Then he uses his remaining 300 psi to surface.

The past

I have participated in recreational scuba and scientific diver training and in commercial and military diving. Those involved in training divers are obligated to have people less confused at the end of instruction than when they started.

There are problems with emergency air sharing. I hope to give you a better understanding of how the present situation developed and to persuade you to convince your communities to try to simplify emergency air sharing.

The Undersea Medical Society, now the Undersea and Hyperbaric Medical Society, convened an Emergency Ascent Training workshop in December 1977. Thirty-five experts representing training organizations in all facets of diving spent two full days discussing the topic. Position papers and statements were compiled in a publication and made available to the diving public. Reactions to the positions were also recorded and published. There was a strong emphasis on unaided ascent as well as on air-sharing ascents.

During the years since the conference there has been little, if any, progress towards standardisation of the latter emergency procedure. Recommendations have come from many sources and small groups within the diving field have instituted programs for their own divers.

Emergency procedures should meet certain criteria if they are going to be effective for large populations. The procedure needs to be

1 Standardised.
2 Easy to learn and reinforce.
3 Logical and require a minimum level of skill.
4 Reliable and effective.

Swimming ascents

Twenty years ago an emergency ascent was all very simple. One did a swimming ascent. One took ones regulator out of ones mouth, tipped ones head back, blew bubbles and swam to the surface.

The military called this a "free ascent", a term which recreational divers immediately picked up. Some of the training agencies, like the Los Angeles Underwater Instruction Agency, insisted that divers had to be able to do a free ascent from whatever depth they dived to. That was considered ones safety valve. If a diver was going to dive to 30 m, the diver had to demonstrate that one could, on a single breath, get all the way to the surface, exhaling all the way. We all managed to do it and no one gave it much further thought. As time went by, the US diving medical community told the training agencies that free ascent was a dangerous practice which should not be done, either in training or in any other circumstances.

Buddy breathing

The way round this prohibition was "buddy breathing", again a military practice. Diving was supposed to done in buddy pairs. It was the responsibility of each member of the buddy pair to be there to help if needed. The procedure for sharing air was very simple. One swam up to ones buddy and drew a hand sharply across the throat, giving the signal that one wanted to share air. The buddy would immediately take the two hose regulator out of his mouth, roll it over and put it into position so that the recipient could get a couple of breaths. Then the donor would roll it back and so on. At the same time as buddy breathing commenced, the divers would hold each other, so they were securely linked together. This particular technique works very well, if one has been trained to execute it. But buddy breathing was the thing that one did only if one could not make a safe swimming ascent to the surface.

With single hose regulators, one took the mouthpiece from ones mouth, passed it immediately to the side and then back and forth. After some accidents we realised we had to teach people that they had to exhale during the time they were not breathing from the regulator. The concept was that one had to see bubbles at all times except when inhaling from the regulator. Had we been really on the ball at that time, we probably would have have suggested that the airless buddy could put his or her mouth over one exhaust valve outlet, block off the other and breathe the expired air. Two people can breathe off a single regulator with very little difficulty if they practice the skill.

Sharing air did lead to some horror stories such as, "I gave my buddy the regulator and he would not give it back". The failures of the buddy breathing system led to remarks about how dangerous it was and that one would have to fight for ones life if one gave ones regulator to someone. Every time I read, in a accident report, that the buddy system failed, I get livid. The buddy system does not fail, it is the people using it that have the problems. The system is fine, it is the implementation that falls down. Usually that is because of lack of practice.

Secondary regulators

The octopus (spare regulator) concept was a logical step. Theoretically if one has an extra second stage all a recipient has do is swim up and put it in their mouth. Unfortunately when the octopus was accepted a major error of judgement was made as we violated a basic precept in emergency procedures. We failed to standardise the location of the spare second stage and failed to standardise the procedure of air sharing.

Shortly after the octopus came in I asked a diving group the question "What would you do if you run out-of-air and you wanted to share my air?" The whole group put an open hand in front of my face. I did not understand what they meant. They explained that they were going to grab the regulator out of my mouth and I would give it to them because that signal meant "I want to take a breath". Unfortunately only they knew what that signal meant. If they dived with others they would not be able to communicate.

Even if one communicates the basic issue of "I'm out-of-air. I want to share" there are two scenarios.

In the first one, the person with air takes his primary life support means and puts it in the buddy's mouth and then has to find his spare second stage. I like to keep my primary regulator and give my buddy my alternative air source. I know the primary works, but I am not certain about the octopus. It takes very little particulate material to create problems with the mechanism of a 2nd stage. The octopus should be in a convenient place where the buddy will get a clean regulator and where both divers can find it. Is it necessary to give up the primary air source? Do I have to give up the one in my mouth that I know is working? I do not have a problem and I do not want one. We may have a problem, but it is really my buddy's problem. I will help in any way I can but if we are going to have an emergency, I want to keep it simple.

In the second scenario the out-of-air buddy takes the spare second stage. Unfortunately it is unlikely that the buddy knows where it is going to be because most divers permit their octopus to hang loose. Mostly the regulator hangs somewhere, even down between people's legs if it is on an extra long hose, dragging in the sand. Some divers even position the octopus so that that one cannot tell whether they have a one or not.

My point is that there is still no standardised procedure for octopus breathing. There is a standardised procedure for buddy breathing, although in some programs buddy breathing is no longer taught, neither is the swimming ascent.

Whether we use buddy breathing, octopus breathing, breathing from an alternate air source or from a pony bottle one has to have a procedure, standardisation of the action and common agreement on how this is going to work.

Some of the manufacturers' innovations are located in a standardised position. The Air II, a breathing device, is always on the end of the inflation hose and incorporates the ability to automatically inflate the buoyancy compensator while still being able to be used as an alternate air source. This eliminates one low pressure hose.

However the Air II requires that both buddies know how it works, which buttons do what. The manufacturer's instructions say that when someone comes up and indicates "I'm out-of-air and I want to share" one gives them ones primary device. But this advice is not because the primary regulator is in a standard position where the buddy can get it. It is because they hope you know how Air II works and accept that your buddy may not.

At UCLA we completed some experimental behavourial studies. We found that one can leave the primary in ones mouth and hand ones buddy the Air II. Certainly it is on a short hose, all that does is bring the buddy in a little closer. One does have to turn it to the outside which results in the hose kinking. However it is very, very difficult to prevent any air coming out of a low pressure hose, with about 140 lbs of pressure in it, by kinking it. There is always sufficient pressure to activate the Air II. However it was shown to be important that the air source be in a fixed position in order to avoid delays in the smooth pass to the recipient's mouth. Velcro or other attachments need to be substantial enough to hold the second stage in a stable position but must allow easy disengagement.

Diving is now a technologically driven sport, driven by incredibly rapidly expanding technology. We used to think it was an instruction driven sport. Perhaps in the early days it may have been, but no longer.

Instead one or two new products per year, we see a multitude of new products, innovations on existing products, and a burgeoning diversity of equipment, resulting in a diversity of methods of handling functions. Other manufacturers have the copied Air II. They are all basically a breathing device that is incorporated into the automatic inflation system. There are probably a dozen variations, all with different kinds of controls, all requiring specific training in order to make the device work.

One needs to have a standardised procedure for using a second regulator and both parties must understand the rules. To make sure both buddies understand the procedure one should try it out on the surface before the dive. During an actual emergency is not the ideal time to try to learn how unfamiliar equipment works.

Pony bottles

Pony bottles have the advantage of being a completely separate air supply. They have the disadvantages of not having a standardised location for the spare second stage and of being a another thing to take on every dive because one does not know when an emergency is going to occur. The one thing about emergencies is that they occur with sobering suddenness according to Murphy's Law.

An enterprising gentleman in California, recognised that people did not like the idea of the large pony bottle, but did want an independent secondary air supply. He came out with Spare Air, a small cylinder of compressed gas, with a regulator on top and a way of monitoring of how much gas is in it. One turns it on before a dive. If one works in a heavy current, it may be activated and bleed off. But if one waits until the emergency to turn it on, the person wanting air may get a little tense during the operation. The manufacturer suggests keeping it in a holster. The diver comes up, gives the signal and one whips it out and hands it over and they are ready to head for the surface.

Spare Air does not require that you break the primary life support link. It has the advantage that you can fill it from a scuba cylinder. The manufacturer found an incredible market, not only divers but also helicopter crews who have actually bought more than divers. When a helicopter goes into the water, it usually inverts and everyone is confused and it sometimes take several minutes to get out. If one can not breathe, escape gets to be dicy. With Spare Air they have several minutes to find a way of getting out and be saved.

Spare Air has a drawback. The early ones simply did not give enough air at depth. At 50 m, one got one full breath and a part of another. At about 18 to 24 m one would get anywhere from 4 to 7 breaths and on the surface 14 to 16 breaths or so. They have now come out with a 3,000 psi cylinder. It is available as a set of doubles.

The problem is that the devices will work well, but in order for them to work every time the spare air source has to have a standardised location, standardised procedure and users with a common set of rules to be able to utilise it in a safe and effective manner.

The ideal is that if you are outfitted with a primary, an octopus, a pony bottle, a Spare Air or a Air II, in a standard location, then when the buddy comes up, they can say "I think I'll have one of these" and life will go on.

Standardisation

One of the big criticisms of the number of devices is it is always possible that the recipient may not know how to use the secondary air source and therefore grabs the primary regulator. The donor then has to sort out the problem, otherwise the other diver is likely to panic. From a human factors point of view it does not make any difference what system one uses. The basic steps one has to go through are the same. There has to be some linkage of the divers and there has to be a transfer of an air source.

If the devices were located in the triangle between the edges of the rib cage and the mouth, this would make it easy to find them. In our tests placement of the air source anywhere in that triangle resulted in an easy pass, as long as the hoses, if any, passed over the shoulder or were attached near the shoulder in a fashion to permit the air source mouthpiece to be placed in the recipient's mouth.

In this discussion you will note that the recommended procedures would not require the donor to remove the primary regulator from the mouth except in the case of buddy breathing. Mounting the alternate air source within the triangle formed by the mouth and the outside lower borders of the rib cage has several advantages:

1 The air source has a consistent, semi-permanent location.
2 The air source is visible to recipients as they approach.
3 A single movement with the right hand can quickly move the air source to the recipient's mouth.
4 A single basic behaviour pattern is possible for the recipient and donor.

One must do the simple things, standardise the location of the alternate air source and standardise the procedure so that whatever signals are given are standard, and the response is to get an air supply from what the diver happens to be carrying. Buddy breathing even works with this system, for people who still utilize this practice. The procedure has to be kept simple. If it is complicated the amount of training needed to overlearn the skill increases dramatically. To learn to use an octopus properly takes over 12 tries to get it right, and this is with a standardised location. Buddy breathing takes from 17 to 21 tries.

Regardless of which system one uses, if both people are not prepared by training, having overlearned the skill to the point where they do not have to think about it during an emergency, it is going to be difficult to perform. If you go into a problem solving mode at the same time as you are involved in an emergency, it is quite likely that you will screw up whatever you decide to do. Any emergency skill must be learned so that it is essentially reflex. The diver can then deal with some other issue and still be able to go through the mechanics of air sharing without thinking about it, whatever else is going on. One of the things that needs to be done in training programs is that when novices have learnt the mechanics of air sharing, they then need to do some rehearsals under additional stress. They need to be able to solve other problems at the same time they are air sharing. One of these problems is propulsion. What tends to happen is while buddies solve the air sharing problem they usually stop swimming. They need to be trained to do two or three things at the same time as they are air sharing. It is amazing how few people can do this.

If one has stress involved in whatever emergency procedure one is going to use, or anticipates that one is going to use, one uses more air. That is the nature of stress. The solution is stress avoidance and reduction. To reduce stress, there are various things we can do. One is mental rehearsal. I once did a research project that showed that one can get reinforcement of individual skills, learning and maintaining those skills if one does mental rehearsal exercises. One imagines going through the process of whatever is going to take place. The difficulty in the case of sharing air, is that both people have to rehearse the same technique under the same mental set of conditions. Talking is a most important way of reducing stress and one that is very rarely used properly. One asks ones buddy "How are we going to handle an out-of-air situation?" and the buddy says "By buddy breathing". Yet you really have not communicated how you are going to do the action. One can bet that what happens is not what you expected, unless you both trained in the same program, on the same system and with the same set of conditions.

There are other problems coming. The recreational diving community is getting interested in the technological aspects of diving. When asked about mixed gas diving, nitrox diving or deep diving, base your advice on what recreation is all about. If they are insistent that they wish to do such diving, then they need training by some competent organization that specializes in that particular sort of diving. This is because how they they do their emergency procedures will vary according to the equipment that they are going to wear. If they do not train in that equipment for particular kinds of emergencies that are likely occur, it is unlikely that those emergencies are going to be successfully handled.

Conclusions

Without getting involved in the controversy over which of the techniques for air sharing is the best, an examination of the problems reveals a procedure which would meet the above criteria with a minimum of retraining or expense. Both the donor's response to the out-of-air signal and the recipient's actions shourl be standardised.

If the diver does not take independent action in the form of a controlled emergency swimming ascent we have an individual who goes to a potential donor for air. The "out-of-air" signal (hand drawn sharply across the throat) followed by the "I want to buddy breathe" signal (hand and fingers motioning toward the mouth) could be given during the initial contact regardless of the manner in which the air supply exchange would proceed. A person who wants air would therefore always follow the same procedure.

1 Signal out-of-air.
2 Signal for sharing air.
3 Establish contact with the donor.
4 Guide the offered air source to the mouth without taking it from the control of the donor.

The donor should respond by
1 Grasping the other diver's harness or tank and facing the recipient.
2 Immediately pass an air source across to the mouth of the recipient who will now be facing the donor.

So far the procedure is well established in the field and should present no new problems. The donor may be prepared to share air by
1 Using buddy breathing.
2 Using an alternate second stage.
3 Using a device such as the Air II.
4 Using a redundant system such as a pony bottle.
5 Using some other suitable device.

Unfortunately there are a number of variations within each of these procedures which complicate the problem of standardisation. However the donor holding part of the recipient's gear while passing an air source can be standardised. These moves can be done quite easily if the air source is in a consistent location where the donor can, in a single move, grasp the air source and pass it to the recipient's mouth. The recommended location is on the front of the chest in the triangle between the edges of the rib cage and the mouth.

The principle issue is that when the individual who wants to share air comes to the donor, the same procedure is always followed. This behaviour then triggers a response from the donor that is functionally the same with regard to the mechanics of the movement irrespective of other factors, such as the type of device being used to share air.

The establishment of a standardised procedure does not mean that dive buddies should feel that there is no need to discuss or even rehearse the procedure prior to the dive. Training is paramount in any emergency procedure.

There is a learning curve associated with the skill of air sharing. In the case of buddy breathing, a study conducted by the the UCLA Diving Safety Research Project determined that 17-21 successful attempts were needed for performance without errors in a group of basic students. Retesting, after three months of diving without reinforcing the skill, showed degraded performances, involving errors in procedures. Not only should the skills be well learned, but they should be periodically reinforced, especially in circumstances where the buddies are diving together for the first time. Use of alternate air source breathing such as alternate second stage, Air II, pony bottle, etc., also involves the learning of a series of skills. These procedures are as complex as buddy breathing up to the point of sharing. The basic difference is that the recipient receiving an alternate air source need not alternate breathing with the donor. This is a substantial advantage in many cases. It is folly, however, to assume that these alternatives to buddy breathing do not require substantial learning and reinforcement.

It is possible to conceive of "what ifs" that could create additional variables and interfere with a smooth procedure. Adequate training, education and dive planning will still be required in order to minimize the "what ifs" and their effects.

This is an edited text derived from a lecture with slides and from the text of a previous publication provided by Dr Egstrom

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RESPIRATORY FUNCTION IN INTENDING DIVERS

Andy Veale

Introduction

The history of diving medicine has moved through a number of different phases. Firstly, divers simply went diving to accomplish a particular aim, there was no consideration at all about the physical or physiological attributes necessary to perform this work safely. Occasional deaths and illnesses then occurred, and attempts were made to explain these deaths using physiological and pathological knowledge obtained in other situations and in other disorders. Rules have then been derived from these extrapolations. Of necessity these rules or standards, are conservative due to the lack of basic knowledge, the desire to be exhaustive and to avoid any perceived medico-legal risks. Finally, the "natural" data accumulates and research data is collected, suggesting that theoretical concerns have been overstated and standards are ultimately relaxed. One very good example of this is the relaxation of standards for aircrew following spontaneous pneumothorax in all Air Forces.

I believe diving medicine needs to become more scientifically rational in terms of risk assessment in order to be perceived by the diving community as acting in the interests of divers, to avoid the "them and us" situation.

Lung anatomy and physiology

I shall briefly cover some aspects of the normal lung anatomy and physiology before pointing out some of the changes in normal physiology which occur during diving. I will then discuss some of the possible mechanisms of barotrauma and how these have been used to justify some of the theoretical risks, and hence contraindications, in current diving standards. I will then discuss the actual risk data, and the potential pitfalls in interpretation of this data, before proceeding to a brief philosophical discussion of what the doctor's role should be.

The lung is a very elastic structure which tends to collapse towards functional residual capacity (FRC). FRC represents a balance between the tendency of the lung to collapse and the tendency of the chest wall to spring out. Most of the lung elasticity is in the bronchovascular bundles which contain most of the elastic and non-elastic connective tissue. The bronchi and vessels tend to run together within bronchovascular bundles and during inspiration or overinflation there tends to be a tractional force along these bronchovascular bundles. Within the walls of the bronchi smooth muscle is oriented in a circular or spiral fashion, becoming increasingly discontinuous toward the terminal bronchioles, leading to areas of potential weakness.

During a normal forced expiratory curve flow rate rapidly reaches a maximum and then falls as the airways become narrower, acting as a flow limiting step. Flow at low lung volumes is thought to reflect flow within the small airways but even in these terminal portions of expiration, flow is still significant at around 800 ml per second.

The compliance of the chest wall and lungs varies considerably with the phases of respiration. Starting from expiration increases in lung volume cause little change in intrathoracic pressure. However at the extreme of inspiration a very small increase in volume is associated with a marked increase in intrathoracic pressure. So any reduction in depth (pressure) while a diver is at total lung capacity (TLC) will very rapidly increase the intrathoracic pressures and as a result the tractional forces along the bronchovascular bundle.

During head out immersion there are significant changes in pulmonary physiology. The lung becomes much less compliant due to the central redistribution of blood volume, closing volume is increased and specific airways resistance and the work of breathing are increased dramatically.

Increasing gas density leads to progressive, and quite marked, declines in flow at all lung volumes.

The net effect of these changes, together with the viscosity of water through which the diver must swim, leads to significant work, not only in respiratory terms but also for the swimming muscles. Swimming at 0.85 knots raises oxygen consumption to six times normal which is close to the maximum aerobic threshold for normal people. The physical work of sport diving is an important, and under-recognised, factor in assessment of diving fitness and contributes significantly to drownings.

Pulmonary barotrauma pathology

The pathophysiological mechanisms of pulmonary barotrauma are entirely unknown. Two possible mechanisms which may occur are alveolar rupture, where alveolar over-distension rather than over-pressurisation leads to shearing stresses on the alveolar bases where they abut the bronchovascular bundle or adjacent segments. The second possible mechanism relates to the tractional forces which may develop along the longitudinally oriented bronchovascular bundle. The circular smooth muscle becomes increasingly discontinuous and spiral towards the terminal bronchioles. In asthmatics who die in during an acute attack it has been shown that bronchiolar glands and ducts can rupture through the bronchiole wall, leading to interstitial emphysema. It is not known whether this mechanism also occurs in divers.

During inspiration lung volume increases and the alveolus enlarges. At the same time there is an increase in intrathoracic blood volume which causes a lengthening of blood vessels and an increase in their transverse diameter During expiration the reverse of this occurs and hence the relationship between the alveolus and the vessel remains constant. If there is alveolar distension without a corresponding increase in intrathoracic blood volume, a shearing stress between the alveolar base and the vessel may cause rupture of the alveolar lining epithelium and basement bundle. This mechanism of causing interstitial emphysema of the lung was clearly explained in the 1940s.[1] In divers hypovolaemia is very common and could exacerbate these shearing forces.

Pulmonary barotrauma

Air within the bronchovascular connective tissues may lead to interstitial emphysema and if this tracks toward the mediastinum, to pneumomediastinum and subsequently to surgical emphysema. If air ruptures through from the mediastinal pleura or from subpleural blebs into the pleural space, a pneumothorax will occur. If entry is into a vessel then arterial gas embolism occurs.

I have an X-ray of an asthmatic woman, taken shortly before she died, showing marked pulmonary over-inflation with surgical and mediastinal emphysema. Her heart was squashed flat by the high intrathoracic pressure. The over-inflation was not air-trapping behind obstructed bronchi. It is due to air in the pulmonary interstitium which tracked along the bronchovascular bundles to the mediastinum. The steadily increasing amount of this interstitial air raised the intrathoracic pressure. Small bronchi and vessels were compressed by this air.

Pneumothorax may be subtle or it may be obvious. A tension pneumothorax can be rapidly fatal.

CAGE pathophysiology

Arterial gas embolus may be fatal at onset, or more usually, bubble transit through the cerebral circulation may result in subsequent reduction in cerebral flow, causing neuronal dysfunction.

These physiological and physical factors, and the serious disorders which may occur in divers, have led to the suggestion that disorders associated with air flow limitation, with gas trapping, with intrapulmonary gas collections, or with patchy lung scarring, should all be contra-indications to diving with compressed air. This has led to the application of the “What if this were to occur at depth” test, without the consideration of the probability of “it” occurring. Many of us have said that whilst there is no definitive proof, there are sound physiological and physical reasons why people are likely to be at an increased risk and we have consequently been restricting large numbers of potential divers.

Discussion

Colebatch looked at pulmonary compliance in six divers with pulmonary barotrauma, comparing them with sixteen divers of similar dive experience but without barotrauma, and demonstrated that the barotrauma divers had a significant reduction in pulmonary compliance: their lungs were stiffer.[2] In this population there were 500 divers at risk of barotrauma and only six developed barotrauma. Of 26 normal divers, three had reduced compliance of similar degree to those with barotrauma, and if this is extrapolated to the total diving population at risk in this study, namely 500 divers, 58 would have been expected to have similar reduced compliance as those diver who suffered pulmonary barotrauma.

In a number of studies of submarine escape and in the military, pulmonary barotrauma has been shown to be a very uncommon event although it must be appreciated that considerable pre-screening has occurred. Professor David Dennison at the Brompton Heart and Lung Institute has examined many survivors from pulmonary barotrauma with specialised pulmonary function tests and high resolution thin section computerised tomography, and has been unable to demonstrate significant abnormalities of lung function which would predict the occurrence of pulmonary barotrauma. Brooks, Pethybridge and Pearson showed that in 34 cases of barotrauma in 3,788 escape tower ascents, forced vital capacity (FVC) < 2SD predicted 8/34 while the ratio of forced expiratory volume at one second (FEV_1) to forced vital capacity (FEV_1/FVC) < 75% would only predict 1/34.[3]

In the Australasian series of 100 deaths reported by Edmonds and Walker[4] nine deaths occurred in divers who were asthmatic. Only two of these showed evidence of PBT. In reported cases of arterial gas embolism there has been only one asthmatic reported in forty episodes of arterial gas embolus treated at Catalina Island, there were none in the 42 cases reported from Hawaii and in the Auckland series of 125 civilian divers[5], of whom one-third had arterial gas embolus-type syndrome, there were also no asthmatics. This data by itself is not entirely reassuring as the denominator, the number of asthmatics who have dived without getting arterial gas embolism, is unknown.

In a paper in the British Medical Journal, Farrell and Glanville[6] reported 104 asthmatics who had dived for a number of years, producing a combined total of 12,000-plus dives without incident. These divers were a self-selected population obtained through a magazine questionnaire however, and again the denominator is unknown.

Spontaneous pneumothorax and thoracic surgery are also conditions which conventional wisdom says are contraindications to diving. Tom Neuman, in recent book on diving medicine edited by Bove and Davis[7], comments that there has not been one incident in the USA Accident Data Base of a diver with past spontaneous pneumothorax or thoracic surgery developing barotrauma or arterial gas embolism while diving. One reason for the lack of incidents may be that these people are screened out by doctors already, and hence the denominator is extremely small. However, this does raise the question of whether we should apply the principles of risk assessment to each individual case, rather than using black and white "standards".

The final part of the puzzle is to look at whether the incidence is great enough to justify mass screening and restrictive rules. In New Zealand PADI train 95% of all trained divers. There are 7,000 new divers trained each year. The numbers of untrained divers who take up the sport each year is unknown but the untrained proportion is likely to be reducing each year. These 7,000 new PADI divers will perform 70,000 dives in their first year and it is quite conceivable that an excess of 200,000 or 250,000 dives are performed each year in New Zealand. Ten of these end in death, the majority from drowning, and 50 end in a recompression chamber. As I mentioned, none of those survivors in the recompression chamber when examined, have shown evidence of abnormalities of lung function or have been asthmatic.

We now come to what a physician's role should be. Are we to act as advisers for divers, in which case it would be perfectly appropriate to advise an asthmatic not to dive on theoretical grounds stated but to teach them ways of overcoming these theoretical risks, i.e. reinforce sound diving practice. Should we administer black and white rules which brook no discussion and exclude any grey area, or could we, with the intending diver, weigh the evidence.

Would it not be best for knowledgeable and experienced doctors to perform a good history and examination, to use such investigational tools as seem appropriate for risk assessment and education; taking account of all the available information, including the mental and general physical state of the person before them; to discuss the risks of diving and give appropriate advice?

Recommendations

I believe the following recommendations are justifiable.

I think that the medical examination for intending divers should be compulsory as it is in New Zealand. I think that this examination should be performed by a doctor knowledgeable about the hyperbaric and diving environment and with a good understanding of the certainties and uncertainties of the advice to be offered. I think that every diver should undergo an FEV_1 and FVC at entry and if there is a history of asthma or of past pulmonary disorder then tests of pulmonary physiology may be useful. These should be performed not for a pass-fail response but as an aid for explanation and rational discussion. I think doctors should advise and support.

In my experience the majority of intending divers who see a doctor they perceive as knowledgeable, caring and acting in their interest, will take the advice offered and be very grateful for it. The same is not the case for an existing diver who has dived for ten years and seeks higher certification, who is then advised that he can't dive because his FEV_1/FVC ratio is less than 70%.

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This is an edited transcript of a paper, illustrated with slides, delivered for Dr Veale, at the 1991 SPUMS Annual Scientific meeting held in the Maldives.

Some references have been provided by editorial staff where they could be easily worked out from the Editor's library.

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SPUMS ANNUAL SCIENTIFIC MEETING 1992

DIVING SAFETY, WHERE ARE WE GOING ?

John Knight

Summary

Diving safety, as for all safety, requires an attitude of mind as well as technical competence. It requires the proper equipment which must be well maintained. Inexperienced and out of practice divers dominate the diving deaths. Diving is always a serious business, but should be enjoyable. Diving for fun may mean that the diver does not bother to dive safely. Current training turns out divers who need extra training to dive safely anywhere other than where they have been trained. Experienced divers seem to be able to avoid problems if they take care.

Introduction

Scuba diving is an intrinsically dangerous sport as it is performed in an unbreathable medium with a limited air supply. It is equipment dependent. The scuba diver must have a reliable breathing system to survive. Raised nitrogen partial pressures change a diver's thinking. Immersion alters physiology and being in water increases heat loss. A diver can kill himself (or herself) by holding his breath and rising in the water. Sea conditions can change rapidly and become dangerously hostile.

Decompression sickness is an unavoidable hazard of scuba diving or any sort of diving. It is very, very, difficult to come up slowly enough to form no bubbles at all. It is a statistical accident whether one forms enough bubbles in the wrong places to get decompression sickness symptoms. There is quite a lot of evidence that coming up faster than 18 m per minute is associated with cases of decompression illness. There is also evidence that multiple ascents during a dive are associated with decompression sickness.

Breath-hold divers continue to die unnecessarily every year. Post-hyperventilation blackout has been known for about 30 years, but its dangers are regularly forgotten. One of our past guest speakers bore the scars of two chest drains and a tracheostomy, the results of a post-hyperventilation blackout in the university swimming pool. He was lucky to be rescued and revived with CPR. Thechest drains were needed for the pneumothoraces CPR gave him ! He went on to become a Diving Medical Officer in the USN.

Safe diving

What is a safe dive ? Is it one where the diver never makes a mistake or is it one when he or she survives to get back to land alive, or more importantly alive and well ? That is a huge range from which to take your pick. Diving is always a serious business, but it should be enjoyable to avoid stresses which can cause disaster. Diving for "fun" may mean that the diver does not bother to dive safely.

Diving safety requires an attitude of mind as well as technical competence. It requires the proper, well maintained equipment. It requires knowledge of the physiological effects of immersion, of hypothermia as keeping warm underwater is difficult, of the effects of partial pressure changes to name but a few requirements. It requires thought on the part of the diver. It requires judgement and courage to stick to doing what is safe, to refuse to dive because one is not happy with some aspect of the dive, often the weather or sea conditions.

Diving safety is the ability to cope with the changes and dangers of diving which leads to safe, incident free diving. Safety does not necessarily come from regulations, such as depth limits. The Queensland regulations were brought about by the failure of self-regulation in the diving industry. A few cowboys were careless and unsafe and their antics, and the importance of the diving industry to tourism, prompted what many see as unnecessarily heavy handed regulation. Equipment provision can be improved by regulation but it does not effect attitude changes.

The efforts of Carl Edmonds, Bob Thomas and others, myself among them, have popularised and raised the standard of diving medicals over the years. However only one instructor organisation (NASDS (National Association of Scuba Diving Schools) which was the Federation of Australian Underwater Instructors (FAUI) until recently) considers that a diving medical is required before the prospective diver gets wet. It is unfortunate that the diving instructor organisations refused to support properly conducted diving medicals during the preparation of the new Australian Standard 4005.1-1992.[1] I consider the questionnaires that are offered are less satisfactory methods of sorting out those who should not dive. Australia is lucky in having a large number of doctors who have had training in how to do a proper diving medical.

Last year Glen Egstrom told us of the rates that his research had shown divers came to the surface.[2] I do not think that many people actually come up at the recommended rate of 10 m per minute or less that is being advised for some diving tables and computers This rate is extremely difficult to achieve. One has to watch the depth gauge and timing device closely to make sure one rises at the correct rate. Usually I have to hover for a while because I have exceeded the ascent rate.

Accidents

What causes accidents ? It is usually diver error, and usually a series of errors. The common errors can be classed as incompetence, which can be due to inadequate training or lack of knowledge, or stupidity, such as going diving when one should not or without required equipment. The divers who died in the Mt Gambier sinkholes were either untrained in the special skills necessary for safe cave diving or did not use them properly. Sometimes the cause is beyond the diver's control such as an unforeseeable event like sudden regulator failure or an unpredicted storm.

Statistics of deaths and DCI, which are almost the only statistics about the problems of diving, are only the tip of the iceberg of errors and accidents. It is only recently that studies of diving incidents have been published. This is largely because the statistics are difficult to collect. They have shown that some pretty startling things happen without morbidity.[3,4]

Thanks to the work of Douglas Walker, in Australia with Project Stickybeak, and John McAniff, who runs the National Underwater Accident Data Center (NUADC) at the University of Rhode Island in the U.S.A., we know the factors that were associated with many deaths. Their reports started in the early 1070 and have appeared regularly since.[5,6] The most important of these appear to be inexperience and being out of practice. Unfortunately the common causes of disaster include failure to act on the part of the diver. Failure to control buoyancy properly. Failure to monitor the contents gauge and failure to start the ascent with plenty of air. Failure to inflate the buoyancy compensator. Failure to drop the weight belt. Failure to recognise dangerous sea conditions. More effective training would teach divers to avoid all these mistakes.

In a number of cases there has been equipment failure that has precipitated the pattern of events that led to a death. This seems commoner in the US deaths than in the Australian and New Zealand deaths.[7] There are many more occasions when equipment failure occurs but is coped with without any problems.

If one is relatively close to the surface when the regulator O-ring blows it is not very difficult to get back to the surface. It is a bit more difficult when one is at any depth and the regulator suddenly refuses to give any air or free flows. One way to the surfaces is to do an emergency, out of air, swimming ascent. Another escape routeis that the diver can breathe in and out of the buoyancy compensator, which will be expanding as one goes up.

If one runs out of air one should immediately head for the surface. That is where there is certainty of getting another breath and perhaps of being rescued. Too many people have died after failed air sharing. I have no faith in the ability of every diver to breathe out at the correct rate while attempting a controlled swimming ascent, free ascent, buoyant ascent or any other sort of ascent without the regulator in the mouth.

Stress, if nothing else, is likely to mar the performance. There is also the risk that the effort of swimming will use up the diver's oxygen reserve and cause unconsciousness from hypoxia.[8] This of course leads to a drowning death. There is a better way of coping with emergency out of air ascents. The **continuous breathing cycle ascent protocol** was published in the SPUMS Journal in 1978[9] with follow up articles in 1982[10] and 1984.[8]

The introduction of this protocol led to a large reduction in out-of-air accidents leading to death or requiring treatment at the Hyperbaric Unit at Tobermory in Canada. Between 1974 and 1982 there were 37 serious diving accidents in the Tobermory area of which 15 died, 12 without ever reaching the surface. By September 1984 there were so few diving accidents requiring treatment that the chamber was virtually unused.[8]

The **continuous breathing cycle ascent protocol** is

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.

In other words keep the regulator in the mouth and try to breathe in and out all the way up. Attempting to breathe in and out will keep the larynx from closing and so decreases the chances of bursting a lung. As one rises in the water the pressure in the cylinder will eventually exceed the ambient pressure and let one take another breath. If you really want to make it to the surface you should blow the expense and drop your weight belt as soon as you run out of air. The cost of replacing your weight belt will probably encourage you to watch your contents gauge more closely on your next dive.

Where is diving safety going?

There is no doubt that the standard of instruction has risen but I have some doubts whether it has risen far enough. Diving instruction organizations in Australia now qualify people as Open Water Divers according to AS 4005.1-1992.[1] Unfortunately they need not have done a boat dive, they need not have dived anywhere except in sheltered water and they do not have to be able to work out all the questions on decompression table problems correctly. They are said to be trained properly in buoyancy control but looking around when I have gone diving, this is not always being achieved. The Australian recreational diver standard does not say the diver is trained to dive anywhere, as did the old C-card. He or she is trained to dive in the area in which he has been trained and needs further training before being safe to dive elsewhere.

Unfortunately I suspect that this extra training is not likely to occur for two reasons. One is that it represents an extra cost and the other is that divers like to think that after their training they can dive safely anywhere. I have been consulted by a number of people who were trained in Queensland, without a thick wetsuit, who dived in Victoria with a thick wetsuit, and got into trouble with their buoyancy, their ascent rate and decompression illnesses.

I know the economic incentives for short courses to teach people to dive. However, I think that many of the people who are trained these days, are not receiving a fair deal. They are being turned out as not "quite safe" and not "quite unsafe" divers. They need more supervision and practice in doing the things that are the more difficult to do, like buoyancy control, floating at a level and ascending slowly. We have got to teach people that they have to look at their contents gauges more often than they do and to look at their depth gauges and their timer as well as to do all the other things they are taught.

Where should diving safety go ?

I hope the standard of training will continue to rise. I am sure that the length of time underwater should be increased considerably before a person is certified as capable. It really seems to me that when somebody can become an "Advanced Diver" by doing two courses which total about 14 or 15 dives, the word advanced is being used very loosely. Experience based on a proper grounding in essentials is the only way that somebody can develop into an advanced diver. Glen Egstrom said it took up to 21 tries at buddy breathing for his students to do it properly every time and that they required reinforcement every six months or they became incompetent.[11] This suggests that every time a diver has a six months lay off from diving the first dive should be in sheltered or easy diving conditions so that he or she can re-establish the self confidence, properly based on competence, which enables one to be safe underwater.

One still sees people who have bought a new piece of equipment who, quite obviously, cannot use it. It is usually a buoyancy compensator. They cannot use it properly, they are not comfortable with it because the buttons for inflation and deflation are different from their last one. It takes time to adapt to new equipment. Just being shown, in the shop, how it works without it being attached to the tank, is hardly a proper instruction in how to use a new and complicated piece of equipment.

My 1977 decision, as the Secretary of SPUMS, to insist that all those diving with SPUMS must have buoyancy compensators was greeted, in some quarters, with dismay. In those days some people still considered that one did not need to compensate for wet suit compression, or abdominal compression, decreasing ones volume and making one relatively heavier. In 1977 we were lucky that nobody burst a lung when they activated their buoyancy compensators, because at least three people came rapidly to the surface in a flurry of foam. This happened because they had not been taught how to use their new buoyancy compensators.

The rise in the standard of instruction does not seem to have made any difference to the number of people who do not understand how to use their decompression tables. It is sometimes advanced in favour of diving computers that they are simpler to understand than the tables as they tell you what to do, so that the diver does not have to understand anything about decompression theory. This may be a practical solution when computers no longer allow unsafe repetitive dives but it is a "cook book" solution, liable to go wrong with the present generation of diving computers.

Some years ago one of the diving instruction organizations wrote to SPUMS asking for advice on what we thought was important in the final exam before qualifying people as divers. The Committee felt very strongly that the trainee should be able to pass a test on using the tables without making a mistake. As far as I know this advice has not been implemented.

Those are the things that will have to be addressed in the future of diving safety. The training agencies have the responsibility to make sure that every diver can control buoyancy properly, knows the hazards of depth (nitrogen narcosis, cold, increased use of air, increased risk of decompression illness) and sea state, can always calculate decompression requirements accurately, is determined never to run out of air underwater and knows how to reach the surface even if unconscious. This involves dropping the weight belt and inflating the buoyancy compensator. Knowing all these things does not detract from ones enjoyment of a dive.

It is lucky that human beings are tough and our bodies can stand a great deal of ill treatment. Otherwise there would many more diving accidents with serious consequences than there are at present. But we should not rely on this to reduce diving accidents.

What is needed is the attitude that diving safety is the diver's responsibility and this requires education in depth and a serious attitude to safety. Both Brett Gilliam's report[12] and Bob Halstead's survey[13] show that depth limitations are ignored safely by many experienced divers. The reason is probably that they are careful to dive safely and avoid making mistakes. Perhaps they are properly prepared for every eventuality or perhaps they know how to keep out of trouble and when to abort a dive. Perhaps they even know, as should every diver, what to do if they do get into trouble and how to contact assistance. Australia has a good recovery system for the Barrier Reef, but it is only as strong as the weakest link, which is usually a human.

Diving safety depends on having fit, well trained, thoughful, competent divers using well maintained equipment who are sensible enough not to do anything stupid or foolhardy.

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This paper presents the views of Dr John Knight which are not necessarily those of SPUMS.

Dr John Knight, FANZCA, DipDHM, has been Secretary and President of SPUMS and is at present the Editor of the SPUMS Journal and the Public Officer of SPUMS. His address is Suite 304, 126 Wellington Parade, East Melbourne, Victoria 3002, Australia.

DIVER RESCUE AND RETRIEVAL IN NORTH QUEENSLAND

Geoff Gordon

The presence of generally fine weather and warm sea temperatures makes diving in the tropics very attractive and further conspires to increase both the number of dives per day, and the length of each dive. Most of this diving takes place in areas remote from tertiary medical facilities. As dive numbers increase so does the incidence of significant decompression illness (DCI). There is thus the need for a coordinated and capable response in order that afflicted divers are treated expeditiously.

The problem

During 1991 in Townsville, 70 divers were treated for DCI, 33 (48%) being retrieved from their dive locations. These 33 included 24 who were retrieved and treated in the Duocom portable recompression chamber (RCC) during transit (Figure 1).

Traditionally this type of work was the domain of the armed forces, but as recreational diving has increased in popularity, the incidence of DCI has clearly exceeded the military's capacity to respond, and as such, the responsibility has been borne by State health authorities.

Our capability

In Townsville our response group consists of trained medical personnel from the Hyperbaric Medicine Unit, with aircraft and specialised equipment, originally provided by the National Safety Council of Australia (Victorian Division) (NSCA), which is currently owned by the Bureau of Emergency Services. These are a Beechcraft Super King Air turboprop fixed win aircraft, a Bell 412 helicopter (Figure 2) and a Duocom portable RCC.

The Duocom is a 240 kg pressure vessel, with an internal volume of 0.7^3 and a working depth of 50 msw. It is fitted with a built in breathing system (BIBS), a medical lock, an intercom system, a CO_2 scrubber and a Nato flange for transfer under pressure. With this chamber we take 4 x G size cylinders, two of oxygen and two of air, an additional 220 kg.

With a Duocom, ancillary equipment and personnel aboard, both available aircraft exceed their maximum all up weight (MAUW) on take off, and on landing have a rearward centre of gravity, requiring especially skilled pilots to transport this equipment safely. Because of these operational factors, we elect not to carry the Duocom by helicopter, but rather to collect the diver from the nearest appropriate air field in the King Air.

Cost

The King Air costs approximately $1,450 per hour to run (crew included) and the Duocom approximately $600 per trip and up to $1,300 for an international retrieval. Typical cost for a Duocom retrieval from Cairns to

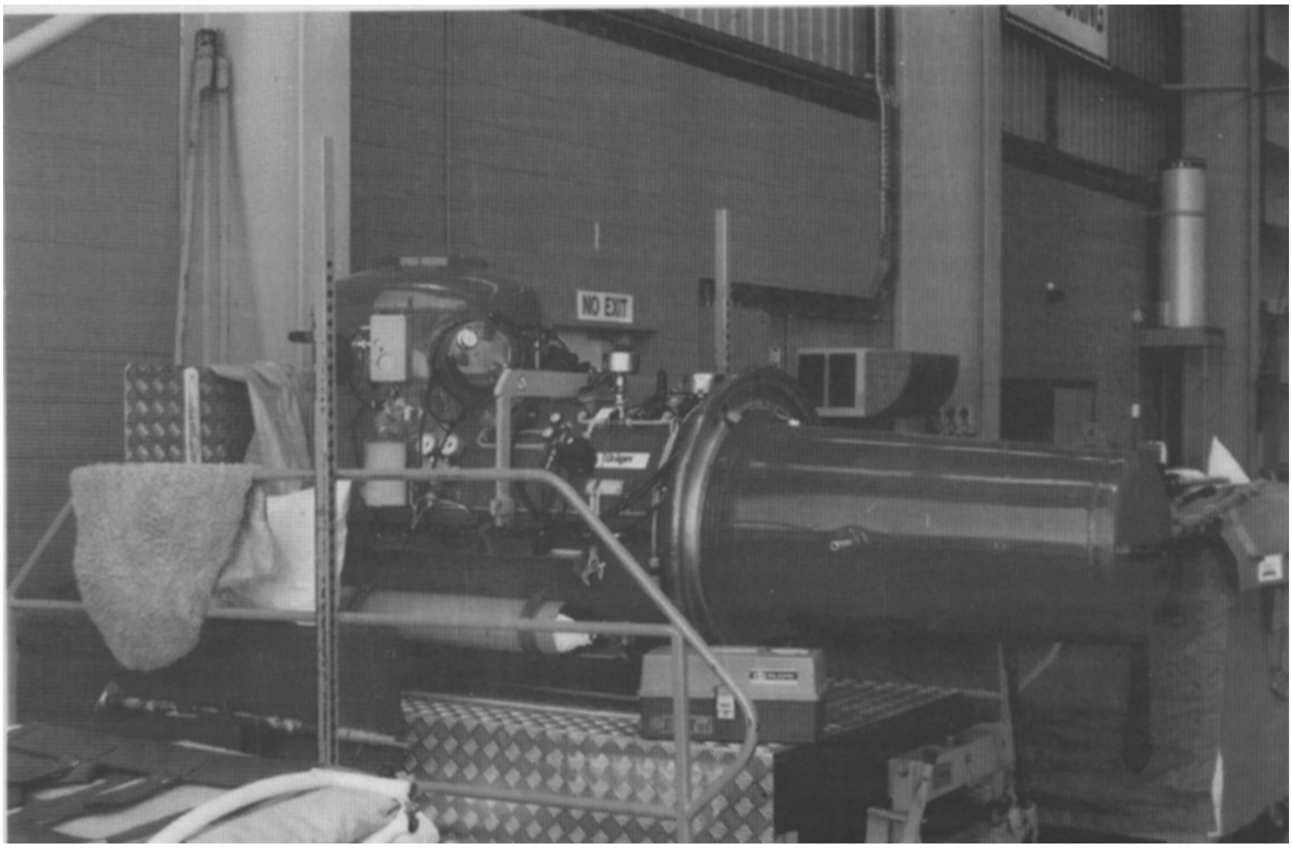

FIGURE 1. Dräger Duocom portable recompression chamber. The right hand end of the chamber fits into the main chamber (Figure 3) and the circular flange locks on so enabling transfer under pressure. When both chambers are at the same pressure the "toe" of the Duocom can be removed and the patient slid out.

FIGURE 2. Bell 412 helicopter with a Dräger Duocom, open with its “toe” lying beside it, in the background.

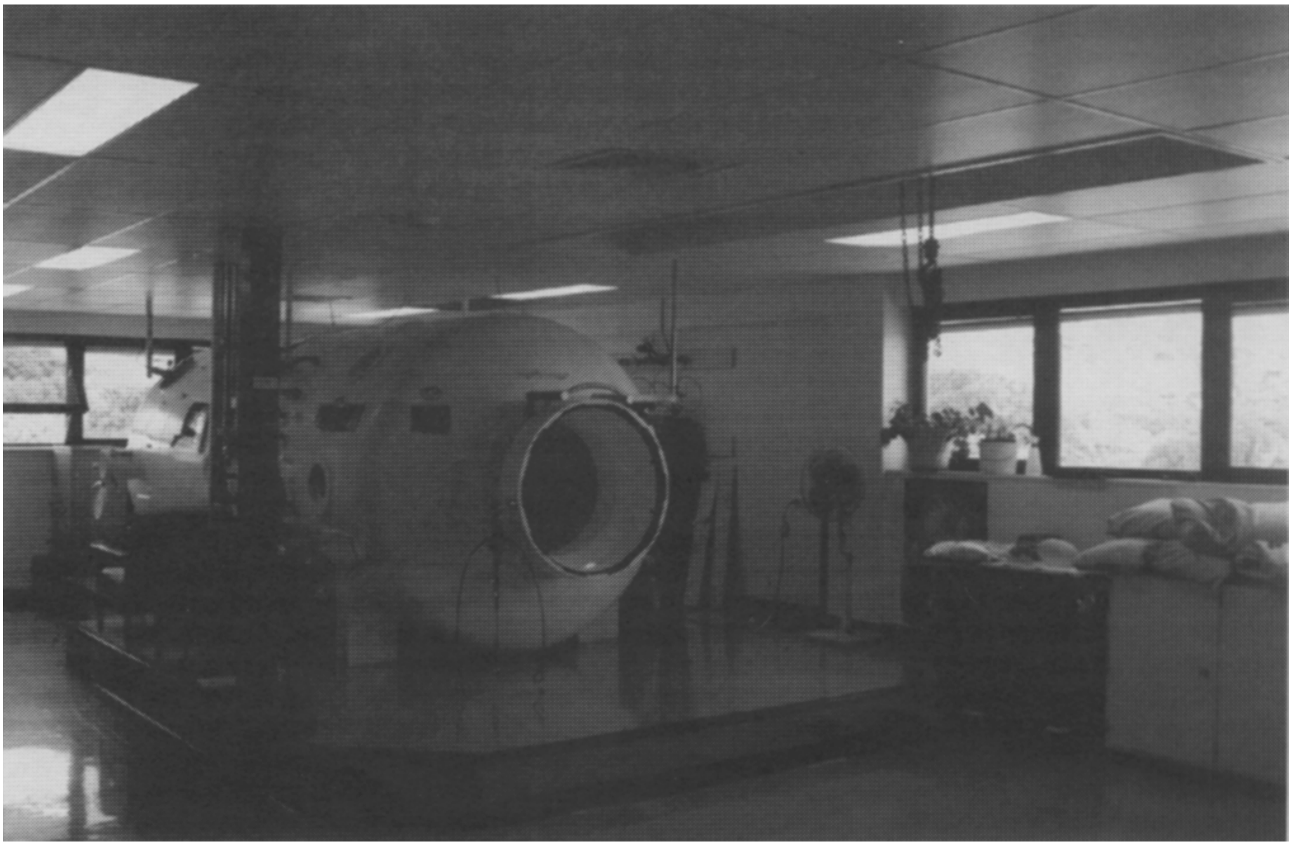

FIGURE 3. The double lock chamber at Townsville General Hospital. The Dräger Duocom locks onto the flange on the entry port. It is manoeuvred into place using the travelling hoist set in the ceiling.

Townsville, taking approximately 3 hours, is $3,000 plus staff salaries.

In overseas retrievals the cost is always borne by the diver or by his or her insurance company.

Communications

For all accidents occurring in Queensland, we are usually first contacted by the DES network, and as most of these divers are Australian, the Health Authority meets the costs. For divers who are not eligible for Medicare, and for those retrieved from overseas, the financial aspects are dealt with by one of the medical retrieval agencies, and they subcontract the work to our unit in Townsville.

We have collected divers from Cape York to as far south as the Gold Coast, and offshore from PNG, Fiji, Nauru, Port Vila and the Solomons. With increasing diver awareness we expect this work to increase.

Treatment

In all patients our initial first aid is

1 85% or greater oxygen via appropriate mask and circuit;

2 the patient is positioned horizontally if air embolism is a possibility;

3 aggressive rehydration intravenously.

If we are using the Duocom, we initially compress to 18 msw with the intention of treating using a RN Table 62 profile of pressure and time. We have the option of going to 50 msw in deteriorating cases.

On arrival in Townsville, the diver is transferred, under pressure, to the main chamber in the Hyperbaric Medicine Unit of the Townsville General Hospital (Figure 3), where the treatment profile is completed. Follow-up recompressions are conducted as is required following repeated patient assessment.

Conclusions

Any retrieval service must satisfy the objective that it is "to improve patient care". Stated more simply, the care given during transport must equal or better the management at the point of referral.

There can be no doubt that our service fulfils these objectives, and as it is yet to be determined whether early retrieval and treatment ultimately reduces morbidity, any caring society is obliged to support activities its community indulges in. This earlier treatment may reduce the incidence of some of the irreversible conditions related to scuba diving. As inexpensive insurance becomes readily available to all divers, the onus of cost will fall on the consumer, and clearly, the divers will want to be recompressed as early as possible, putting additional pressure on hyperbaric units to run efficient retrieval services.

Dr G.S. Gordon, BHB, MBChB, FFARACS, FANZCA, DipDHM, is a Staff Anaesthetist at the Townsville General Hospital. His address is P.O. Box 670, Townsville, Queensland 4810, Australia.

The photographs were taken in October 1991 by Dr John Knight during a visit to Townsville. Then retrieval organisation was then the North Queensland Emergency Response Group.

REPORTS OF OTHER DIVING AND HYPERBARIC MEETINGS

HYPERBARIC TECHNICIANS AND NURSES ASSOCIATION (HTNA) FIRST ASM

Hyperbaric nurses and technicians in Australia founded the Hyperbaric Technicians and Nurses Association at their first Annual Scientific Meeting in Adelaide on August 28th and 29th 1992.

The Association aims to promote and encourage the exchange of information between members; to standardise protocols and practices within the technical and nursing communities affiliated with the HTNA; to educate and inform the recreational diving community of developments that affect safe diving practice and standards; and to establish training requirements for hospital based chamber technicians.

The HTNA encourages members to join SPUMS and is closely affiliated with the Australian and New Zealand Hyperbaric Medicine Group, which is a Standing Committee of SPUMS.

Full membership is open to nurses and technicians currently working in the field of Hyperbaric Medicine.

Associate membership is for individuals or groups who have an interest in the aims of the Association.

Corporate membership is available for those companies or organizations that wish to support the aims of the HTNA.

Officers for the 1992-1993 year are:

President:	Christy Pirone
Secretary:	Steve Goble
Treasurer:	Andrea Jones
State representatives:	
New South Wales	Barry Spiers
Victoria	John Houston
South Australia	Bob Ramsay
Western Australia	Sharon Keetley
Northern Territory	Dave King
Queensland	Allison Mann
Tasmania	Sean Rubidge

The Annual Scientific Meeting was attended by 40 hyperbaric nurses and technicians from nine different hyperbaric units around Australia.

The first day opened with a keynote address by Professor Bill Runciman, Head of the Department of Anaesthesia and Intensive Care at the Royal Adelaide Hospital and Chairman of the Quality of Practice Committee of the World Federation of Societies of Anaesthesia. He gave a superb account of the role of oxygen in evolution, entitled, "Oxygen - The Fire of Life".

Dr "Fred'" Gilligan, Director of Retrieval Services and "Forefather" of Hyperbaric Medicine at the Royal Adelaide Hospital, gave a particularly interesting history of Hyperbaric Medicine in Australia. Fred is an excellent source of not only hyperbaric and retrieval knowledge, but also hyperbaric historical facts and trivia.

Scientific papers were presented by Mandy Wilson (Hypobaric decompression illness - a case history), Jodie Perris (Differential diagnosis: DCI vs Irukandji stings), Henri Bource (The role for a private hyperbaric unit), Bob Ramsay (An alternative to steel for hyperbaric chamber construction), Sue Sheeran (Monitoring in a hyperbaric environment, Sydney style), and Dr Frank Quigley (Diagnostic and prognostic tests for ulcers; prediction and outcome).

A Safety Forum included an introduction to the Hyperbaric Incident Monitoring Study by Christy Pirone and a most "enlightening" presentation by David McGowen on "Fire safety and the hyperbaric environment".

An Open Forum was held after the Annual General HTNA Business Meeting which produced much constructive discussion about dive tables, diving community education, hyperbaric research around Australia, and hyperbaric unit databases.

The quality of presentations and the discussion generated at the meeting was of a very high standard. Most attendees felt the meeting was very useful and long overdue.

The next meeting is to be held in tropical, warm sunny Darwin on August 6th, 7th and 8th 1993. Plan your next holiday for Darwin with the HTNA!

Membership application forms are available from

Steve Goble, HTNA Secretary,
Hyperbaric Medicine Unit, Royal Adelaide Hospital,
North Terrace, Adelaide,
South Australia 5000.

GLEANINGS FROM MEDICAL JOURNALS

SELECTED ABSTRACTS

Reprinted from the Program and Abstracts
of the
UNDERSEA AND HYPERBARIC MEDICAL
SOCIETY

ANNUAL SCIENTIFIC MEETING
23rd-27th June 1992

The address of the Undersea and Hyperbaric Medical Society, Inc. is 9650 Rockville Pike, Bethesda, Maryland 20814, U.S.A.

DIVERS AND ASTHMA

Observation on asthma in the recreational diving population.

Bove AA, Nueman T, Kelsen S and Gleason W. *Undersea Biomed Res* 1992; 19 (Supp); 18

Asthma is considered a contraindication to diving because of concern for pulmonary barotrauma due to lung over inflation during ascent from diving. However, asthma is extremely prevalent in the US (estimated to be 5-8% of the population). It seems likely therefore that a sub-population of sport divers may have asthma, and clinical experience indicates that some asthmatics are participating in sport diving. Evaluation of the rationale for considering asthma as a contraindication to diving requires data on the role of asthma in diving-related illness to determine if asthmatic divers are at increased risk for diving accidents. Through a screening study in the consumer publication Skin Diver Magazine, (Petersen Publishing Co, Los Angeles, paid circulation 211,041), 10,422 responses to the question “have you ever had asthma” were returned from readers of the magazine. 870 (8.3%) answered yes, 343 (3.3%) indicated that they currently have asthma, and 276 (2.6%) stated that they dive with asthma. This screening study confirms field observations of asthmatics participating in diving. While this initial study does not support an exact projection of the number of asthmatic divers, it has isolated a group of asthmatic divers for further study.

From Temple University, Philadelphia, Pennsylvania and the University of California, San Diego, California, U.S.A.

A survey of diving asthmatics.

Corson KS, Moon RE, Nealen ML, Dovenbarger JA and Bennett PB. *Undersea Biomed Res* 1992; 19 (Supp): 18-19

Asthma has traditionally been considered a risk factor for decompression illness in scuba divers. In order to characterize scuba diving asthmatics, in August 1991, a questionnaire was placed in *Alert Diver*, of which approximately 75,000 were mailed. By January 1992, 279 questionnaires were returned. Sixty-three percent were male. Mean age was 37.4 years (range 15-75). Two-hundred forty-three (88.7%) responders took medication for asthma, and 55.8% took medication pre-dive. Seventy-three (26.4%) individuals had been hospitalized for asthma, of which 20.7% had been hospitalized 1-5 times, and 5.8% had been hospitalized 6 or more times. Onset of asthma began under age 14 in 57.4%. Of those who wheezed, 13.3% had symptoms daily, 17.3% weekly, 26.2% monthly, and 43.1% annually. There were a total of 56,334 man-dives reported by 269 individuals. There were 11 cases of decompression illness reported in 8 individuals. The calculated risk of decompression illness in questionnaire responders (1 in 5,100 dives) significantly exceeds the estimated risk for unselected recreational divers[1], with an odds ratio of 4.16 (χ^2=119.4, p=0.00001). We conclude that the risk of decompression illness is higher in the surveyed asthmatics than in an unselected recreational diving population. Further investigation will be needed to quantify this risk according to the degree of severity of asthma.

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From the Divers Alert Network and F.G. Hall Hypo/Hyperbaric Center, Duke University Medical Center, Durham, North Carolina, U.S.A.

DECOMPRESSION ILLNESSES

Concordance: a problem with the current classification of diving disorders.

Smith DJ, Francis TJR, Pethybridge RJ, Wright JM and Sykes JJW. *Undersea Biomed Res* 1992; 19(Supp): 40

Using the current classification of the decompression disorders[1], a diagnostician is frequently required to make a diagnosis which assumes a disease mechanism or site of injury. To examine how consistently this can be done, 47 diving physicians agreed to “diagnose” 50 case histories selected from INM case records covering a two year period. The participants were asked to make a differential diagnosis, allocating an index of confidence (0-100%) to each diagnosis, or to state that there was insufficient information on which to base a diagnosis. Five cases were excluded from the analysis because “inadequate information” represented more than 10% of responses. Five cases had predominantly non-DCS diagnoses. In 3 cases the predominant diagnosis was from the “Type I” DCS category, but in 11 cases, there was inconsistent discrimination between “Type I” and “Type II” DCS. Some observers chose as alternative diagnoses conditions from both the “Type I” and “Type II” categories. In 7 of the 22 “neurological” cases, there was poor discrimination between AGE and “Type II” DCS (i.e. >20% mean confidence ascribed to each diagnosis). This inconsistency was found both within and between individuals. Of the four cases diagnosed as “audiovestibular”, inner ear barotrauma was not clearly differentiated from labyrinthine of cerebral DCS. Concordance was calculated as the mean of the confidence ascribed to the “most likely” diagnosis for each case averaged over the 45 cases. It was calculated to be 52%. While it is recognised that it can be difficult to make diagnoses based upon case histories alone, each diagnostician was given identical information. These initial results indicate that, using the “current” classification there is poor agreement between physicians diagnosing the decompression disorders.

Reference

1. Elliott DH and Kindwall EP. Manifestations of the decompression disorders. In : Bennett PB and Elliott DH eds. *The Physiology and medicine of diving*, 3rd edition. London: Balliere Tindall, 1982; 461-472.

From the Institute of Naval Medicine, Alverstoke, Hants PO12 2DL, U.K.

Climatic and environmental factors in the aetiology of DCI in divers

Broome JR. *Undersea Biomed Res* 1992; 19 (Supp): 17

Decompression illness (DCI) may occur unexpectedly after “safe” dives and in the UK unexplained clustering of cases has been observed. It was hypothesised that the weather and environmental factors may influence the occurrence of DCI. INM diving accident records were searched and all cases of DCI for the 6 years 1984-1989 extracted. Cases with historical features traditionally associated with arterial gas embolus were excluded. Records were required to contain clinical details, date and time, location, depth, and duration of the dive(s) preceding DCI. 177 records fulfilled these criteria. The climatic and tidal conditions prevailing at the time and place of each dive were ascertained from Meterological Office archives and Admiralty Tide Tables. Dive profiles were compared with an arbitrary standard, RN Air Decompression Table 11, and depending on whether dives conformed with or exceeded the time/depth profiles recommended, they were allocated to an index "safe" group or control "risky" group.

These groups were further subdivided depending on whether single or multiple dives had preceded the onset of DCI. Group numbers were: 42 "safe" dives of which 36 were single and 6 multiple, and 135 "risky" dives of which 80 were single dives and 55 multiple. Climatic and environmental data for each group was compared by χ^2 analysis of contingency tables for each environmental variate. It was found that "safe" dives were more likely to result in DCI if the surface environment was cold. Significant differences were found in air temperature and wind chill ($p = <0.001$ of all dives, <0.01 for single dives) and for air minus water temperature ($p = <0.01$ for all dives, <0.05 for single dives) when prevailing conditions at the time of the "safe" dives resulting DCI were compared to the "risky" dives. For surface water temperature the difference between the two groups failed to reach significance when single dives alone were examined but $p = <0.02$ for all dives. No statistically significant difference was found in barometric pressure, change in barometric pressure between the time of the dive and symptom onset, wind speed alone, or tidal factors between "safe" and "risky" dives. The results imply that exposure to a cold thermal environment following diving, particularly when the air temperature is cooler than the water temperature, may be a more important risk factor for the development of DCI than has hitherto been assumed.

From the Institute of Naval Medicine, Alverstoke, Hants PO12 2DL, U.K.

A retrospective review of the epidemiology of diving accidents treated at Naval Station Roosevelt Roads from 1986 to 1991 and implications for improving diving safety in Puerto Rico.
Sholar JB and Ames JW. *Undersea Biomed Res* 1992; 19 (Supp): 20-21

One hundred and eight diving accidents treated with emergent recompression therapy at Naval Station Roosevelt Roads between 1986 and 1991 were reviewed. Eighteen per cent of these accidents involved military members, 13% involved recreational divers, and 69% involved commercial spearfishermen. The diving accident diagnosis was DCS II in 61% of cases, DCS I in 18% of cases, and AGE in 21% of cases, while the initial treatment rendered was 38% USN TT6, 43% USN TT6 with extensions, 15% USN TT6A, and 4% USN TT5.

Treatment was delayed over 6 hours in 71% of cases and was delayed over 12 hours in 29% of cases. Ninety two per cent of the injured Puerto Rico civilian divers were outside the tables. Furthermore, only 17% of the civilian divers were certified although 86% had over two years diving experience. Over 85% of civilian divers were diving repetitive dives deeper than 80 fsw for multiple days. Thirty per cent of the civilian divers treated had residual symptoms requiring repetitive hyperbaric oxygen treatments, and there was only one fatality. Of the 15 patients requiring repetitive treatments in 1990 and 1991, 9 recovered, 3 achieved independent ambulation with an abnormal gait, and 4 remained wheelchair bound. These figures indicate that the large majority of diving accidents treated in Puerto Rico are associated with inadequate training and improper diving practices which may lead to significant permanent disability. It is postulated that increased educational efforts and stricter regulation of access to compressed air would improve diving safety in Puerto Rico.

From the U.S. Naval Hospital, PSC 1008, Box 3007, FPO AA 34051-8150.

Gender-related risk of decompression sickness in hyperbaric chamber inside attendants: a case control study.
Dunford RG and Hampson NB. *Undersea Biomed Res* 1992; 19 (Supp): 37

From 1976-1990, Virginia Mason Medical Center carried out 7,910 hyperbaric oxygen therapy treatments exposing approximately 8,424 inside attendants (IAs). In that time, 26 IAs have been treated for decompression sickness (DCS) symptoms (0.31%). A case control analysis showed that the rate of DCS was dependent upon the maximum depth of the exposure ($p<0.0001$) and that exposure ratio for males and females (0.38 to 0.62) was similar to their ratio of DCS (0.31 to 0.69). Of the 9 female IAs whose menstrual history is known, 5 were menstruating when they developed DCS. Assuming 4 days of menses in a 28 day cycle, the risk for DCS in IAs with menses was 7.6 fold ($p<0.01$). Two of 24 female recreational scuba divers treated in the same period were menstruating (8.3%), a rate similar to the percentage of female recreational divers diving during menses (as estimated by survey). The risk of DCS in menstruating IAs is statistically greater than that for open water menstruating divers ($p=0.013$). Comments on the type of IAs DCS symptoms are included. We conclude that for dry hyperbaric chamber exposures there is no gender-related risk for DCS, but significant risk related to the maximum depth of exposure. Menses is a significant risk factor for female chamber IAs but not for female recreational divers in open water.

From the Virginia Mason Medical Center, Seattle, Washington 98111, U.S.A.

Cerebral involvement in decompression sickness.

Pearson RR, Pezeshkpour GH and Dutka AJ. *Undersea Biomed Res* 1992; 19 (Supp): 39-40

There is increasing clinical evidence to suggest that cerebral involvement in decompression sickness (DCS) involving the central nervous system is more common than is evident from all previous studies which rely on diagnostic criteria derived from the presentation, clinical examination and response to to therapy.

The use of new functional imaging techniques has added a new awareness to this possibility and its importance. Using a cranial window in a canine animal model we have been able to visualize and record events in the pial circulation during the onset and development of DCS following a no-stop dive to 300 fsw for 15 min.

These events were related to changes in the cortical and spinal somato-sensory evoked potentials (CSEP and SSEP) generated by stimulation of the median and peroneal nerves. The response to recompression was also studied as well as the consequent histopathology. The results of these experiments indicate that, inter alia:

1 The initial event in altered cerebral function, as measured by CSEP's, is the appearance of arterial gas emboli.

2 In this model, at least, the progression to complete occlusion by gas of the pial arterial and venous circulation is dramatic, often occurring in less than one minute. This process appears to be "fueled" by off-gassing of cerebral tissues into arterial gas emboli that have arrested.

3 Recompression rapidly restores perfusion but, in some cases, clearing of gas had not occurred at 60 fsw.

4 The CSEP's were always affected before the SSEP's suggesting that the brain is significantly more vulnerable to decompression stress than the spinal cord.

5 The resulting histopathology in cerebral tissues was entirely compatible with an ischemic process and correlates well descriptions of acute and chronic pathology in divers.

From the Naval Medical Research Institute, Bethesda, Maryland 20889-5055, U.S.A.

Femoral head decompression sickness as a concomitant of central nervous system decompression sickness.

Smith LA, Hardman JM, Sandberg GD and Beckman EL. *Undersea Biomed Res* 1992; 19 (Supp): 36

Decompression sickness is typically divided into two categories, Type I, pain only disease, and Type II, that disease associated with the central nervous system (CNS). Deficits in sensory and motor function are the predominant signs of DCS of the CNS. The decreased pain sensation can be of such severity as to mask the presence of acute bone DCS. The presence of CNS DCS does not eliminate the possibility of the simultaneous occurrence of bone DCS. It is important to recognize the presence of Type I DCS because of the ramifications of chronic bone DCS, dysbaric osteonecrosis.

To look at thefrequency of concomitant Type I and Type II disease, we compressed young pigs to 150-200 feet of salt water and then decompressed them in such a manner as to produce clinical DCS.

Pathological examination of the brain, spinal cord, and both femoral heads of the animals was undertaken. A significant number of the animals with gas bubbles in their CNS were found to have gas bubbles in the epiphyseal areas of the femoral head, these epiphyseal lesions being indicative of the presence of acute bone DCS. We conclude that acute bone DCS may occur simultaneously with CNS DCS in a significant number of patients and may go unnoticed. Given the possibility of concomitant Type I and Type II disease it would appear prudent that the long term management of patients with central nervous system DCS should include monitoring for dysbaric osteonecrosis the long term sequelae of acute bone DCS.

From the Hyperbaric Treatment Center, 42 Ahui St., the University of Hawaii School of Medicine, and Tripler Army Medical Center, Honolulu, Hawaii.

Presentation of concurrent decompression sickness and carbon monoxide poisoning - treatment with HBO.

Slade B. *Undersea Biomed Res* 1992; 19 (Supp): 31-32

This case presentation is a 32 year old experienced scuba diver successfully treated for combined decompression sickness and carbon monoxide poisoning four days post-dive exposure (day 0). He was a good health prior to the (only) dive, had moderate alcohol intake the night prior, but no other known risk factors for DCS. The patient, his friend and a Mexican guide all noticed an odor "like chemicals" or exhaust fumes in their air supply.

All dived to 100 fsw, but the patient recalls being caught in a current which forced him 20-30 feet deeper than his two buddies. His ascent to join the other divers was difficult due to problems with his dry-suit, weakness and leg cramps, and necessitated a rest stop on a sand shelf at 60 fsw. By this time, low on air and with severe nausea since 15 min into his 35 min dive, he ascended to the surface without a required decompression stop (the other divers still had 1/2 tank of air left). His buddies complained of nausea during and after the dive. On surfacing, he vomited copiously and was so profoundly weak he had to literally be helped out of his gear and lifted onto the boat. He developed bilateral joint pains on day 1. He flew back to the U.S. on day 2 and developed a headache during the flight. All symptoms resolved by day 3 leaving him with residual patchy extremity paresthesias. He returned home on day 4, noted by family and friends to be mentally slow and unstable. He was treated with IV fluids and, on days 5-7, with two USN TT6 followed by three USN TT5. The paresthesias resolved, and he gradually improved. Psychometrics testing was done a total of four times showing gradual improvement, the last test was normal. This combined insult is a disordered decompression. The patient recovered fully.

From the Department of Hyperbaric Medicine, David Grant USAF Medical Center (MAC), Travis Air Force Base, CA 94535.

Radiographic imaging in neurological decompression illness.

Moon RE, Massey EW, Debatin JF, Sallee DS and Heinz ER. Undersea Biomed Res 1992; 19(Supp): 42

All patients with neurological decompression illness (DI) evaluated at Duke University Medical Center who had CT or MRI evaluation of their brain or spinal cord were included in this study, a total of 66 patients. Brain MRI scans were performed in 46 patients, CT scans in 17 (15 with IV contrast) and both studies in 8. Twenty four patients underwent MRI scanning of the spine using surface coils. There were 52 males and 14 females (mean age 34.8 years, range 16-59). All patients were classified into B (brain involvement) or S (spinal cord only). CT scans were classified as normal (N), abnormal with lesion probably related DI (AR) and abnormality probably unrelated to DI (AU), e.g. cerebral atrophy. MRI scans were classified as normal (N), large cortical and subcortical abnormality (AL), small area of increased T_2 signal in the centrum semiovale (UBO) or small area of increased T_2 signal in a region atypical for UBO (AS). AR on CT or AL on MRI were only observed in the presence of an abnormal neurological exam. In the 8 patients who had both studies 2 of the 6 with normal CT had had either AL or AS on MRI; both individuals with abnormal CT also had an abnormal MRI.

Only two individuals had abnormalities detectable within the cord (8.3%). We conclude that CT and MRI are frequently normal in neurological DI. Although statistical significance was not achieved abnormalities appear to be more frequent in the presence of B. These two imaging techniques are less sensitive than clinical evaluation in neurological DI.

CT	Normal	Abnormal Related	Abnormal Unrelated
Brain involved	6	3	2
Spinal cord only	4	1	1

MRI	Normal	AL	AS	UBO
Brain involved	20	3	3	4
Spinal cord only	12	0	1	3

From the Hyperbaric Center and Departments of Anesthesiology, Neurology, Pulmonary Medicine and Radiology, Duke University Medical Center, Durham, N.C. 27710 USA.

Demonstration and explanation of the breach of the pulmonary filter with transesophageal bubble contrast echocardiography.

Harch PG, Gottlieb SF, Van Meter K, Kerut EK and Swanson HT. Undersea B*iomed Res* 1992; 19(Supp); 41

In a companion abstract, a case was presented where Type II DCS was masked as mental illness. We were interested in understanding the mechanism of the CNS manifestations of the DCS resulting from a breath-hold ascent from 30 ft in cold, fresh water altitude diving. To simulate the cardiovascular and pulmonary mechanics of a breath-hold ascent, bubble contrast transesophageal echocardiography was performed. In the absence of a patent foramen ovale, significant numbers of bubbles were detected in the pulmonary vein and left atrium during phase IV of the Valsalva manoeuvre. Blood gas analyses failed to demonstrate significant a-v shunting. The unusual bubble patterns observed may be explained by the cardiovascular and pulmonary vascular dynamics associated with the Valsalva manoeuvre. It is thought that the overshoot of the blood pressure rebound resulting from the rapid surge of venous return and the subsequent increase in stroke volume results in capillary distension and transmission of otherwise filterable bubbles. Alternatively, one would have to postulate the existence of a subclinical, congenital abnormal anatomy.

From the Jo Ellen Smith Memorial Baromedical Research Institute and Jo Ellen Smith Medical Center, New Orleans, Louisiana. 70131,U.S.A.

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