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South Pacific Underwater Medicine Society Incorporated

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OBJECTS OF THE SOCIETY

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

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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.

The subscription for Full Members is $A50.00 and for Associate Members is $A30.00.

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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 or colour slides suitable for converting into black and white illustrations. 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 sickness (DCS) can thereafter be referred to as DCS.

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

The SPUMS Journal is composed on a Macintosh using Microsoft Word and PageMaker. Contributions on Macintosh discs, 400 or 800 k, preferably in Microsoft Word 3, or in any programme which can be read as "text" by Microsoft Word 3, save typing time. They must be accompanied by hard copy set out as in **Minimum Requirements for Manuscripts** above.

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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Telephone enquiries should be made to Dr John Knight (03) 417 3200, or Dr John Williamson (08) 2245116.

ARTICLES OF INTEREST REPRINTED FROM OTHER JOURNALS

GLEANINGS FROM MEDICAL JOURNALS

Abstracts from the Undersea and Hyperbaric Medical Society Annual Scientific Meeting 1991

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PROJECT STICKYBEAK

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

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

EDITORIALS

HIGH TECH DIVING

Intrinsic to the Australasian attitude towards recreation is the belief that there should be absolute freedom of choice and no government or quasi-government intervention (with the exception of funding which is always eagerly sought!). Why then is SPUMS actively campaigning against recreational "High-Tech Diving" (see letter on page 37) and in particular the plans to use scuba apparatus and oxygen-helium, perhaps trimix, gas mixtures to dive beyond 50 msw, and according to some press-releases, as deep 200 msw?

There are two fundamental reasons for the SPUMS campaign. Firstly, freedom of choice, or as it should be called, risk acceptance, requires an accurate knowledge of the actual risk if either the risk is to be accepted or if appropriate support is to be provided. The risks intrinsic to oxygen-helium or trimix scuba diving beyond 50 msw are considerable, even in the context of controlled military diving operations. Consequently, and not surprisingly, commercial diving operators do not undertake such activities. For example, the United States Navy reported a series of seven scuba (oxygen-helium) divers who dived beyond 60 msw and were then subsequently unable to undertake any decompression in the water. All were immediately recompressed to the maximum working pressure, 50 msw, of the on-site recompression chamber and despite this, all seven died! It would appear that survival in this context requires a recompression to at least the depth of the dive, and often an additional 30 msw.

The decompression illness risk, using the United States Navy oxygen-helium bounce diving tables for dives beyond 60 msw and for longer than 30 minutes, exceeds 20%. The "High-Tech Diving" planned for Australian sports divers is to be based on decompression schedules especially developed by Dr Bill Hamilton, PhD. However, Bill's schedules have not been used in this context and Bill has written to SPUMS dissociating himself from deep and especially 200 msw scuba diving.

Use of helium as a diluent gas in diving causes significant thermal stress. Dry-suits are unsuitable beyond 90 msw and below 150 msw the gases supplied to the diver must be heated if severe hypothermia is to be avoided.

Decompression from deep oxygen-helium or trimix bounce-dives invariably require some breathing of 100% oxygen at 12 msw or shallower, to avoid dilutional hypoxia, reduce thermal stress, improve communications and to accelerate decompression. Oxygen toxic convulsions have been a major problem in oxygen-helium, and especially trimix diving. Indeed, such convulsions were one of the major reasons why the Royal Navy abandoned 70 and 80 msw trimix diving trials in 1981. An oxygen convulsion in the water is often complicated by hypoxia, aspiration of vomitus, pulmonary barotrauma and decompression illness (in both the convulsing diver and the other divers in the team). The risks of oxygen toxicity and hypothermia are the major reasons why many oxygen-helium divers use surface-decompression. The cost of this procedure, in the absence of a closed-bell and a transfer under pressure, is a significant increase in the decompression illness incidence.

These are the real, not imagined, risks of oxygen-helium or trimix diving. The use of scuba apparatus beyond 50 msw and perhaps to 200 msw simply exaggerates these problems. It is absolutely essential then that these risks be understood by prospective "High-Tech" sports divers/diving candidates.

The second reason for the SPUMS policy on such diving is related to the cost of the medical care needed for successful treatment of the inevitable accidents. Unlike the United States of America, the majority of injured divers are treated in Australasia at government (i.e. our taxes) expense. These governments then are inevitably and appropriately part of this risk-acceptance process, hence their legitimate involvement in deciding if recreational "High-Tech Diving" should occur. Many divers developing decompression illness after oxygen-helium dives beyond 50 msw will respond well to 18 msw oxygen treatments. However, among those that do not, compression on oxygen-helium (never air) to at least the depth of the dive will be necessary to control symptoms. The majority of Australasia's therapeutic recompression chambers can not undertake such treatments, and for those that can the cost is considerable. For example, a 41 hour oxygen-helium treatment just conducted by the Royal New Zealand Navy (the only body in Australasia involved in the treatment of recreational divers which has any real experience in oxygen-helium diving and its related decompression illness) cost $9,725 in personnel costs alone! This contrasts with typical treatment costs for decompression illness following air diving of about $1,250 for a treatment in the same facility. Also, the recompression chamber is unavailable for several days, at least, with consequent effects on the treatment of other patients, some of whom are paying customers. It follows that the community, and especially the hospitals involved, has every reason to expect "High-Tech" sports divers to pay for the cost of their own treatment.

Recreation should be fun. For some people to have fun, some element of risk is essential. Regardless of the psychology and mentality involved, it is essential that those undertaking high risk activities such as recreational "High-Tech Diving" understand these risks, especially students paying for tuition, and that they accept these risks and can be self-supporting. The inevitable impact on the limited hyperbaric health resource in Australasia is such that these divers must also have adequate insurance-cover (if they can get it) or be able to privately recompense hospitals and Navies.

In view of the above, it is not surprising then that the SPUMS policy on "High-Tech" recreational diving is that it should be actively discouraged and that this Society will not oppose any government who consequently legislates some limit on recreational diving.

Des Gorman, FACOM, PhD, DipDHM.
President of SPUMS.

THE EDITOR'S OFFERING

With this edition of the Journal is enclosed a copy of the SPUMS submission for Appendices A and B to Standards Australia Committee CS/83, Recreational Underwater Diving. This gives the details of what SPUMS thinks is needed for an adequate diving medical. All members of the sub-committee which produced the document, all of whom have done many medicals, take at least 30 minutes to perform this medical, which is why a price linkage to insurance medical fees has been suggested in the past. The sub-committee was of the opinion that only be doing a less thorough, and very superficial, medical could it be done in less than half an hour.

On pages 31-32 is the SPUMS Statement on Diabetes, prepared by the Education Officer, Dr David Davies and approved by the Committee. For a variety of reasons the Society advises against diving by diabetics on insulin.

The editorial by the President, Dr Des Gorman, puts the reasons why the Society is against encouraging High Tech Diving. The reasons can be summarised as safety and cost of treatment. The Society has no objection to divers risking their lives provided they have a full knowledge of the risks involved. The letter from Rob Cason (pages 37-38) is an enthusiasts view. The magazine, AquaCorps, reviewed in the last issue, gives a more balanced view of the risks involved. What is quite certain, as shown by Edmonds et al. (pages 20-24) is that deep diving with current scuba equipment is dangerous at low cylinder pressures, as buoyancy compensators fill very slowly at 40 m, only just deeper than the recommended recreational limit, and if the diver is breathing, which is the usual practice, may not fill before the diver is out of air. To give the compensator the best chance to fill the diver should stop breathing while the compensator inflating button is pressed at depth with a low air pressure. Holding ones breath for up to 40 seconds may be difficult but a full compensator and a dropped weight belt will at least give the diver a chance of reaching the surface alive. Being at 40 m out of air and with an uninflated compensator makes it unlikely that the diver will survive.

Douglas Walker's 1989 Provisional Report (pages 3-15) makes sad reading. Not diving for over 12 months and attempted buddy breathing appear as risk factors for CAGE. Those who dive only on their annual holiday should have an orientation dive, where they consciously practice all their practical diving skills, especially buoyancy control and breathing from both primary and octopus regulators, in a non-threatening environment before doing any serious diving. If they are using their own equipment having it serviced before the orientation dive is an excellent precaution. The report of the deaths of two pearl farm divers from CO poisoning makes a chilling story. Not only were they inadequately trained but the employer condoned them diving dangerously with an inadequately equipped compressor and no one in the boat to supervise its operation. Such are the benefits of free enterprise workplace agreements, unsupervised, whether by default or intent, by those who should enforce safety regulations.

Wienke and Graver (pages 15-20) present a way to use, and the reasoning behind it, the USN tables for multi-level diving. We have to apologise for the complicated way their Table 1 reads. We added, at a late stage in preparation, the depths in m to the authors' in fsw to help those of our readers whose education was in metric and not in imperial measurements. Whether you want to use their method depends on your views about the safety of the USN tables but they have analysed over 16 million possible dives and found none ever exceeding USN M values.

Brett Gilliam's paper (pages 24-30) is certainly the largest and best data-base of sports dives and the associated decompression illnesses. A known incidence of suspicious symptoms of approximately 0.02% (2 in 10,000 dives) and an incidence of treated decompression illness of about 0.01% (1 in 10,000 dives) in tropical waters with many deep dives makes the BS-AC claim (pages 57-60) that the British incidence is steady at about one in 10,000 to 15,000 dives, in colder waters, slightly suspect. With 17 deaths in Britain in 1991 and 100 cases of decompression sickness (DCS) treated, simple mathematics gives a figure of 1,000,000 to 1,500,000 dives a year and death rate of between 0.11 and 0.17 in 10,000 dives. Put another way there was approximately one death for every 6 treated cases of DCS. On these figures the Ocean Quest should have had between 1 and 13 deaths. Here is a field for further research.

From the 1991 AGM comes a description of the development of the PADI Medical Form, a study of the DCS incidence reported to DAN with the PADI Recreational Dive Planner, an evaluation of in-water oxygen recompression therapy conducted in the Antarcticd and the report of the Royal Adelaide Hospital's year shows that divers are not the main users of that hyperbaric unit.

And again Bob Halsted gives us food for though with a case report, in Letters to the Editor, and a call to abolish the term "no-decompression dive".

ORIGINAL ARTICLES

PROVISIONAL REPORT ON DIVING-RELATED FATALITIES DURING 1989

Douglas Walker

Summary

There were 19 cases of diving-related deaths identified as having occurred during 1989 in Australian waters. Three of these were associated with breath-hold diving, 13 were scuba divers and three were using compressor-supplied hookah apparatus. This list, like those in all previous years, may be incomplete because of the lack of reporting of "diving incidents" by, and to, the diving organsiations, which continues to be a (regrettable) fact.

Two of the breath-hold divers were spear fishing, one dying from a cardiac cause and the other following hyperventilation. The third diver is thought to have lost alertness and then drowned when hit on the head by a "frisky" potato cod. On this case, there is deficient data because, like in several other cases, the local Coroner thought the calling of a formal inquest to be unnecessary.

All three hookah deaths (one a double fatality) were due to carbon monoxide poisoning following positioningt of the air intake hose where exhaust fumes from the compressor motor could be entrained.

In the scuba category there were 7 instances where CAGE was either the proved or clinically probable critical factor. Of these two were in relation to aborted buddy-breathing during ascent. Four were persons who had not dived during the preceeding 12 months. The majority of fatalities occurred after separation from the dive partner(s) or in a solo diving situation. Where buddies were in a position to assist they performed well. Examination of the records of these cases confirms the importance of regarding the opinions of pathologists, concerning both their findings and their interpretation of the cause of death in diving-related deaths, as needing analysis and not necessarily to be accepted as being beyond legitimate dispute. This is true even in some instances where the pathologist has appeared to follow a "diving death" autopsy protocol.

Case reports

BH 89/1

Although he had been a keen spear fisherman in his younger days he had given it up for many years because of sinus problems and had only resumed the sport 8 months before the fatal dive. He was on medication for hypertension. Its treatment and severity is unknown but he was known to comply poorly with advice to take his tablets. He swam out to a reef with his buddy, both spearing several fish before reaching it. The buddy wished to continue around the reef to hunt on the seaward side but the victim said he was thoroughly tired and had cramps in his feet and he was going to return to the beach. When he started his return swim his buddy decided follow suit. During this swim they each speared another fish. The buddy was initially 2 m from him but they became further separated and the buddy reached the beach first. He had looked back from time to time and noted his companion's absence from the surface, naturally (and undoubtedly correctly) assuming that he had dived again. After he reached the beach he became concerned because he was unable to see his friend at the surface so climbed up onto some wreckage to obtain a better view. He saw nothing so swam out and then noticed the victim's spear gun on the sea bed. It had been fired. There was no sign of the victim.

His search being unsuccessful, he gave the alarm, but despite the efforts of searchers the body was not recovered till one week later. The weight belt was still in position. The autopsy revealed that he had an enlarged heart and that both coronary arteries were markedly atheroscleotic, with 50-80% narrowing of their main segments. It was assumed that he had suffered a cardiac problem while making strenuous efforts to shoot a fish, then drowned. There is also the possibility that he suffered a post-hyperventilation blackout, particularly if he had been attempting to show that he had lost none of former skills.

SPEARFISHING. SEPARATION/SOLO AT SURFACE. HYPERTENSION. POOR ADHERANCE TO MEDICAL ADVICE. CORONARY ARTERIES NARROWED. ATHEROSCLEROSIS. NO BUOYANCY VEST. FAILED TO DROP WEIGHT BELT. POSSIBLE POST-HYPERVENTILATION BLACKOUT. FATIGUE. NO INQUEST.

BH 89/2

This young man was regarded as a good breath-hold diver but no description of his skill is available. He had recently completed a basic scuba course and was employed on a boat which took tourists to dive on the Barrier Reef, so had opportunities to dive. On this day he was without duties on the boat and was apparently swimming and breath-hold diving near the boat while the passengers were snorkeling or scuba diving at the nearby cod hole. It was not until there was a second query from one of these tourists concerning the length of time he had been underwater that a check was made on the boat and his absence was confirmed. As the divemaster was preparing to enter the water to search for him, one of the returning divers observed the body on the sea bed, in 15 m of water . When the body was raised a bruise was observed over the right eye and although no intra-cranial damage was found at the autopsy the local opinion was that one of the

PROVISIONAL REPORT ON AUSTRALIAN

Case	Age	Training and Experience Victim	Training and Experience Buddy	Dive Group	Dive purpose	Depth m (ft) Dive	Depth m (ft) Incident	Weights On	Weights kg (lb)
BH89/1	42	Experienced	Experienced	Buddy Separation before incident	Spear fishing	Not stated	Surface	On	4 (9)
BH89/2	24	Trained Experienced	None	Solo	Recreation	12 (40)	Not stated	None	None
BH89/3	26	Trained Experienced	Trained Experienced	Group Separation before incident	Cray fishing	4.5 (15)	Not stated	On	12 (26)
SC89/1	26	Trained Some experience	Experienced	Buddy Present during incident	Recreation	12 (40)	Surface	On	12 (26)
SC89/2	35	Trained Experienced	Trained Inexperienced	Buddy Separation during incident	Recreation	18 (60)	18 (60)	On	11 (24)
SC89/3	48	Trained Some experience	Trained Inexperienced	Buddy Separation during incident	Recreation	15 (50)	15 (50)	On	9.5 (21)
SC89/4	37	No training or experience	None	Solo	Recreation	6 (20)	Surface	Ditched Tangled	21 (47)
SC89/5	51	Trained Experienced	Trained Inexperienced	Buddy Separation before incident	Recreation	18 (60)	Ascent	On	7 (15)
SC89/6	36	Trained Inexperienced	Trained Inexperienced	Group Separation before incident	Recreation	14 (46)	Surface	Not stated	Not stated
SC89/7	48	Trained Experienced	None	Solo	Recreation	12 (40)	Not stated	On	Not stated
SC89/8	50	Trained Experienced	Trained Experienced	Buddy Present during incident	Deep Dive	29 (95)	Ascent	On	Not stated
SC89/9	31	Trained Very experienced	Trained Experienced	Buddy Separation during incident	Deep diving Course	33 (110)	29 (95)	On	12 (26)
SC89/10	30	Trained Some experience	Not stated	Trio Separation before incident	Recreation	9 (30)	Not stated	On	Not stated
SC89/11	46	Not trained or experienced	Trained Experienced	Buddy Separation before incident	Crayfish	Not stated	Surface	On	Not stated

DIVING-RELATED FATALITIES 1989

Contents gauge	Bouyancy vest	Remaining air	Equipment Tested	Equipment Owner	Comments
Not applicable	No	Not applicable	Not applicable	Own	Hypertension and fatigue. Coronary artery disease.
Not applicable	No	Not applicable	Not applicable	Own	Possibly hit on head by Potato Cod.
Not applicable	No	Not applicable	Not applicable	Own	Post-ventelation blackout. History of asthma
Yes	Inflated	Low	Significant fault	Borrowed	No dives in the previous 12 months. Leaky mouhtpiece. CAGE.
Yes	Not inflated	Yes	No faults	Own	No dives in the previous 12 months. Vomited. Water aspiration. Possible CAGE
Yes	No	Low	Some adverse	Own	Current. Rough water. Regulator problem. Cardiac insufficiency.
Yes	No	None	Some adverse	Borrowed	First use of scuba. Very experienced with hookah. Contents gauge error.
Yes	No	Low	Some adverse	Hired	No dives in the previous 12 months. CAGE.
Yes	Not stated	Low	Significant fault	Own	No dives in the previous 12 months. Aspiration of vomit. Gauge error.
Yes	Not stated	None	Some advese	Own	Delay of 14 weeks before equipment was tested.
Yes	Not stated	Yes	No faults	Own	Buddy breathing ascent. Safe error in gauge. CAGE.
Yes	Not inflated	Yes	Significant fault	Own	Buddy breathing ascent failure. Mismatch of equipment. CAGE.
Yes	Not worn	None	Some adverse	Own	Left buoyancy compensator in boat. Epileptic. CAGE.
Yes	Not Inflated	Yes	No faults	Own	Cardiac death ?

PROVISIONAL REPORT ON AUSTRALIAN

Case	Age	Training and Experience Victim	Training and Experience Buddy	Dive Group	Dive purpose	Depth m (ft) Dive	Depth m (ft) Incident	Weights On	Weights kg (lb
SC89/12	45	Trained Some experience	Trained Some experience	Buddy Separation before incident	Recreation	12 (40)	Not stated	Ditched	Not stated
SC89/13	42	Not trained Some experience	Not stated	Group Separation before incident	Spearfishing	6 (20)	Not stated	Off Ditched	Not stated
H89/1	16	Scuba trained Inexperienced	Not trained Experienced	Separation	Work	15 (50)	15 (50)	On	Not stated
H89/2	28	Not trained Exprerienced	Scuba trained Inexperienced	Separation	Work	15 (50)	15 (50)	On	Not stated
H89/3	21	Training not stated Experienced	None	Solo	Work	7.5 (25)	7.5 (25)	On	18 (40)

potato cod had been "too frisky" and had collided with him, rendering him dazed or unconsicous and unable therefore to protect himself from drowning. As no inquest was thought to be necessary there are some details not available concerning this case.

SOLO. BREATH-HOLD. DELAY BEFORE ABSENCE NOTED. NO WEIGHT BELT WORN. POSSIBLE HEAD TRAUMA FROM FISH. EXPERIENCED BREATH-HOLD DIVER. NO INQUEST.

BH 89/3

Few if any spear fishermen consider it either practical or even necessary to follow buddy diving procedures or have a surface watcher while spear fishing. It is for such reasons that a post-hyperventilation blackout can so readily result in drowning. This victim was not only a competitive minded spear fisher and hunter of crayfish but was also a scuba instructor. This outing was an end-of-season special dive for the instructor staff of a dive shop and the victim had collected several crayfish while scuba diving in company with the others. They had not practiced any buddy diving discipline because, as the skipper said, "They were not paying passengers". He appeared to consider it natural that they failed to practice what they taught others to do.

It had not been intended that they would breath-hold dive but the sea conditions were so unusually calm that it was decided that they could dive on a reef which contained a wreck, which was close to to their return course. It was only after the others had returned to the dive boat, and had allowed a margin of time for his known determination in the hunt to be fully satisfied, that they became aware of and worried by his absence and started a search. He was found, still wearing his weight belt, lying free on the sea bed in water only 3 m deep. It is probable, but unproven as the belt was lost during the body recovery, that he had been wearing the heavy belt he used while scuba diving. He was reportedly an asthmatic and had been advised for this reason not to continue diving. There is nothing in the history of his diving or of this incident which implicates asthma as a factor. He was reportedly careful to monitor his lung function with a flowmeter before going diving, though such a course cannot protect anyone against bronchial over responsiveness should they inhale a fine spray of sea water during the dive. The circumstances here are typical of a post-hyperventilation blackout followed by drowning. This was mentioned at the Inquest but not noted in the formal findings.

EXPEREINCED BREATH-HOLD DIVER. CRAYFISHING. SEPARATION/SOLO. FAILED TO DROP WEIGHT BELT. NO BUOYANCY VEST. ASTHMA HISTORY. POST-HYPERVENTILATION BLACKOUT.

SC89/1

Although the divers had been trained three years ago the buddy had dived frequently since then, while the victim

DIVING-RELATED FATALITIES 1989

Contents gauge	Bouyancy vest	Remaining air	Equipment Tested	Equipment Owner	Comments
Yes	Inflated stated	Not	Some adverse	Hired	Ditched equipment. CAGE.
Not stated	No	Low	No faults	Own	Rough water. Fatigue. Backpack unbuckled.
Not applicable	No	Not applicable	Significant fault	Employer	Compressor lacked inlet hose. CO poisoning. Delay before being found. Adverse comments on training and work safety practices.
Not applicable	No	Not applicable	Significant fault	Employer	Compressor lacked inlet hose. CO poisoning. Delay before being found. Adverse comments on training and work safety practices.
Not applicable	No	Not applicable	Significant error	Own	Malposition of air intake hose. CO poisoning.

was making his first dive after 12 months without diving. This was a boat dive and also aboard was an instructor with one pupil and a child (who was left on the boat while the others were in the water). The victim and his buddy made an uneventful dive through a narrow cave and emerged after a normal ascent on the other side of the small island. They decided to swim back on the surface around the island using their remaining air, first having exchanged "OK?" signals. After they had been swimming for only a short time the buddy looked back and saw his friend was stationary, so returned to him. He said that he was feeling very tired, so the buddy started to tow him, but shortly after this his eyes rolled up and he lost consciousness.

The buddy managed to pull him up onto a flat rock and was greatly relieved to see the dive boat was coming towards them. The instructor had realised that their dive time was nearly up and had decided to collect them. He swam to the rock and began expired air resuscitation (EAR), first having sent a radio call for assistance. There was no response to his resuscitation efforts.

When the equipment was checked it was noted that there was a fine spray of water with each inhalation, the consequence of a fine hole in the rubber mouthpiece. The autopsy revealed evidence of air embolism, the pre-autopsy X-ray films showing the presence of air in the heart and aorta. It is noteworthy that the ascent was apparently correctly performed and that there was a delay before the onset of symptoms of significance. The inhaled spray may have altered lung function and been a significant and adverse factor in this fatality.

TRAINED. NO DIVES FOR 12 MONTHS. NORMAL ASCENT. SURFACE DELAY BEFORE ONSET OF FATIGUE SYMPTOMS. VALIANT BUDDY RESPONSE. DELAY BEFORE START OF RESUSCITATION. REGULATOR MOUTHPIECE HOLE CAUSED WATER SPRAY INHALATION. CAGE. AIR EMBOLISM SHOWN BY X-RAY. NO INQUEST.

SC89/2

The victim was considered to be an experienced diver but he had not dived during the previous 12 months. He was alert and appeared to be in good health despite having attended a "bucks night" prior to this dive. He was paired with another diver and entered the water first, snorkeling at the surface while waiting. Their descent was slow, as the buddy had some difficulty equalising his ears. The visibility was poor and the buddy was nervous so they maintained close contact with each other, water depth 18 m. After about 5 minutes the victim indicated his wish to ascend and immediately started a rapid ascent without waiting for his buddy to respond. The buddy attempted to keep up with him but was unable to to do so despite inflating his buoyancy vest and made a somewhat panicky, rapid ascent, but reached the surface without ill effects. He could not see his companion anywhere and it was only after he had been taken aboard the dive boat that he saw him floating unconsicous at the surface.

When reached, it was seen that the inflation hose to his buoyancy vest was not attached. It was found that he had inhaled vomit, and this could very well be what triggered his sudden decision to ascend. Although no pulmonary barotrauma or air embolism was detected at the autopsy it is probable that this occurred during his urgent ascent.

TRAINED. EXPERIENCED. NO DIVES PREVIOUS 12 MONTHS. SUDDEN DECISION TO MAKE RAPID ASCENT. SEPARATION FROM BUDDY RESULTED. UNCONSCIOUS AT THE SURFACE. ASPIRATION OF VOMIT. BUOYANCY VEST INFLATION HOSE NOT CONNECTED. WEIGHT BELT NOT DROPPED. INADEQUATE SURFACE COVER. POSSIBLE CAGE.

SC89/3

The buddy was just certificated, the victim trained for a year but still very inexperienced. The dive was well conducted by a dive shop and they were making their second dive of the day and had surfaced after an uneventful dive and ascent when the buddy noticed that the victim appeared to be fiddling with his regulator. The sea was now rougher than when their dive had started. The victim did not answer when asked if he was all right, instead pointing towards the dive boat and then starting to swim towards it. The buddy was therefore not alarmed and he began to swim towards the boat, looking towards his companion occasionally but unable to see him because of the waves. In fact the buddy overswam the dive boat for this reason and was therefore surprised when he reached it to find the victim was not already there. It was only then that the victim was seen floating, face down, at the surface about 40 m from the boat. The buddy immediately swam to him and towed him to the boat, attempting to keep his face above the water. He ditched the victim's equipment and attempted to give EAR resuscitation in the water, a task taken over by the instructor, who had just then surfaced with his pupil and observed what was happening.

The autopsy revealed the presence of anatomically narrow cornary arteries with much of the distal 2/3 of the left anterior descending artery a miniscule vessel. There were some scattered patches of atheroma. They had to swim against a strong surface current to reach the dive boat so it is believed that the effort involved proved too much for his cardiac function and cardiac failure occurred.

TRAINED. INEXPERIENCED. SURFACE SWIM IN CHOPPY WATER. STRONG CURRENT. SURFACE SEPARATION. NARROW CORONARY ARTERIES. POOR SURFACE COVER. NO INQUEST.

SC89/4

A reputation for being experienced should always be taken as being valid only in regards to the specific activity being performed. In this incident the victim had great experience as a hookah diver and he thought he would try scuba diving. He borrowed equipment and arranged to dive with a friend, but did not abandon his plan when the friend was not able to come as had been arranged. A witness saw him walking towards the water and later observed bubbles breaking at the surface when he returned to the beach.

The friend saw the victim surface twice more, apparently in some distress and having difficulty remaining at the surface. He therefore stripped off some of his clothing and entered the water. On reaching the spot he looked down and saw the victim sinking, head down. He was already 1.5 m underwater. He attempted without success to bring him back to the surface but found he was too heavy. He realised that the victim's weight belt and back pack had been ditched and were caught by the catch bag he had tied to his arm. Having no knife he was unable to cut this free so he had to attempt to tow him ashore, putting on the victim's fins to assist his swimming. The body snagged on the sea bed and it was only when another person arrived in a small boat that the victim was pulled to the surface.

SOLO. UNTRAINED. FIRST DIVE WITH SCUBA. EXPERIENCED WITH HOOKAH. OVERWEIGHTED. BORROWED EQUIPMENT. DITCHED WEIGHT BELT AND BACKPACK ENTANGLED ON CATCH BAG TIED TO ARM. NO KNIFE. NO BUOYANCY VEST. VALIANT RESCUE EFFORT.

SC89/5

This victim was a visitor from the USA who had only recently arrived in Australia and gone straight to dive on the Barrier Reef. He correctly claimed to have been diving for 20 years but had got only 200 hours of logged dives, none in the previous 12 months, so was not truly as experienced as the 20 year history suggested. There was no history of any ill health. On the boat taking the divers out to the reef he was given a just-certificated diver as buddy because of his supposed experience. All were well briefed by the divemaster during the trip out and were also checked by him before they entered the water. The water depth here was 18 m maximum and all were told to ascend when their contents gauges showed 500 psi. After about 20 minutes the divemaster saw a lone diver surface, apparently in a normal manner, then became concerned when he saw that he was floating too quietly. He decided to check that all was well and quickly swam to him, about 30 m from the dive boat. The victim was floating face down with limbs outstretched. He turned him face up, ditched his weight belt, cleared his airway, and commenced EAR.

It was now that three divers surfaced nearby, the missing buddy with two others who she had joined when she was suddenly deserted. They had surfaced when the buddy had showed them her contents gauge indicated it was time for her to ascend. The victim was unconscious and cyanosed, with froth coming from his mouth. No pulse was palpable even with CPR efforts. Resuscitation attempts were continued during helicopter evacuation to shore but he never responded. Because of delayed awareness by the police that this was a fatal accident (the victim was taken to a hospital), there was delay in requesting sealing of the equipment and it had been already disassembled and mixed with that used by others on the dive boat before an attempt was made to retain it. An arbitary set was checked and while this showed some faults it was clearly not that used by the deceased. The fact that the equipment was imperfect allayed fears that a special effort might be made to present a perfect (but incorrect) set.

Before performing the autopsy some plain X-ray films were taken and these showed (supine) clouding of both lung fields and (erect) gas shadows in the region of both ventricles and the right coronary artery. When the great vessels were sectioned a large gas bubble was released. The aorta and coronary vessels were healthy and there was no evidence of recent myocardial damage. It was suggested that there was hypertrophy of the left ventricle and cardiomyopathy was diagnosed on the basis of this finding. A surprising suggestion was made that the widow had mentioned a history of ill health. This must be regarded as a doubtful finding.

TRAINED. EXPERIENCED 20 YEARS. NO DIVING PREVIOUS 12 MONTHS. SEPARATION THEN SUDDEN SOLO ASCENT. UNCONSCIOUS AT SURFACE. POSSIBLE ARRHYTHMIA ASSOCIATED WITH CARDIOMEGALY. CAGE. X-RAY EVIDENCE OF AIR EMBOLISM.

SC89/6

Following his basic training 6 years before he had suffered a serious road accident so had made only 5 dives since qualification, none being in the previous 12 months. He was stated to have made a complete recovery despite the prolonged period, about 2 weeks, of unconsciousness he had suffered. Aboard the dive boat there were in addition to him two other trained divers and a group of nine pupils with their instructor, his assistant, a trainee divemaster and a divemaster. It was recognised that the victim lacked experience so he was included for the first dive with five pupils and the instructor. Later, in the afternoon, he dived again, this time with four of the pupils who were making their first unsupervised dive. This, like the first dive, was without incident. They ascended carefully together and at the surface checked their remaining air. Three decided that they had sufficient to return underwater, the victim and one other being advised to surface swim return as they had less air. The buddy was quick to start his snorkel swim, looking back to the victim when reminded to do so by a shout from the boat. He was then 10 m from the victim, who was still where they had surfaced, 80 m from the boat. He appeared to be about to start snorkeling. Close to the boat the buddy dived using his remaining scuba air, and boarded the boat before again looking back. He saw the victim floating at the surface “as if looking at fish underneath”. Soon after this the other three divers surfaced 40 m from the boat, now low on air. They noticed that the vicitm was on his back, unconscious, a little froth coming from his mouth.

He was brought back to the boat and CPR resuscitation started but he failed to respond. The cause of death was found to be aspiration of vomit. He had not given any noticed signal of being in trouble.

TRAINED. INEPXERIENCED. NO DIVING PREVIOUS 12 MONTHS. SEPARATION AT SURFACE RETURN SWIM IN CALM WATER. ASPIRATION OF VOMIT. NO CALL FOR HELP. LOW AIR. GAUGE READ 200 PSI HIGH. INADEQUATE SURFACE COVER. PREVIOUS SERIOUS HEAD INJURY.

SC89/7

As a trained and experienced diver (7 years) this man had hired equipment from his dive club and taken it on holiday with his brother and a friend. He decided to make a solo dive, and after watching for a time as he kitted up, the other two left him in order to visit some of the local beauty spots. On their return at the agreed time they saw his back pack floating some way off the beach, in the bay, then observed the victim floating face down in waist deep water among the rocks. There was a cut in his left temple area but no significant bruising was noticed. All his detatchable equipment was missing. The sea within the bay was relatively calm, though it was open sea, so he should not have been exposed to rough water. Although they believed that the victim was dead they made resuscitation attempts for the next 45 minutes.

The backpack was recovered later floating near to and bumping on rocks in the margins of a channel. It was left unwashed for several days by the finder and then, when nobody came to claim it, was taken to the police station. Formal examination was delayed for months. It was then noted to be showing corrsion and damage, though the person who reported on it was unwilling to accept that it could have been damaged on rocks in rough water conditions. The reason for this fatality was not established, though it appears likely that he experienced some problems and ditched his equipment, later suffering impaired alertness following a blow on his head. The autopsy showed neither drowning nor cerebral damage signs.

Of some interest was the Coroner’s finding that the cause of this incident was a “sudden stoppage of air supply”. This, he stated, “should have caused a sudden panic reflex action which prevented resumption of normal breathing, even when air was again available, until eventually asphyxiation was complete”. It is uncertain who suggested such a scenario to him.

TRAINED. EXPERIENCED. HIRED EQUIPMENT. SOLO. DITCHED WEIGHT BELT AND BACKPACK. DELAY IN EXAMINATION OF EQUIPMENT. EQUIPMENT SHOWED DAMAGE.

SC89/8

Despite the opinion of one doctor that he was unfit to dive because of being overweight he had no absolute medical contraindications to diving and he was passed as Fit to Scuba Dive after a correct medical assessment. He had made over 90 dives without trouble and was now taking a Deep Diver Course and had previously passed an Advanced Diver Course. The dive was in a deep part of a harbour and involved an instructor with six pupils. On the bottom each demonstrated his basic skills (masks clearing, doff and don the equipment, buddy breathing) and they were then instructed to make a buddy-breathing ascent up the anchor line. Water depth here was 30 m and visibility was poor.

The buddy thought the victim was akward with buddy breathing and when they reached about 18 m depth the victim changed over to the use of the buddy' octopus regulator, and at about 9 m depth he let this be loose in his mouth. The buddy pushed it back into his mouth in the correct position and they continued their ascent, the buddy replacing the regulator each time it was about to fall from the victim's mouth. Naturally, and correctly, the buddy omitted the planned (but not essential) deco step at 3 m and continued straight to the surface. From 9 m depth the victim did not appear to be alert.

At the surface the buddy noted vomit coming from the victim's mouth. The buddy inflated the victim's buoyancy vest and called for assistance. The victim was rapidly brought aboard the dive boat and it was there noted that he was not breathing and had a faint pulse. Resuscitation was commenced immediately with EAR, CPR being initiated when the pulse could no longer be palpated. This was continued until management was taken over by an ambulance crew.

The autopsy was conducted without adherance to the technique considered by diving medicine experts to be correct. Indeed the pathologist involved declared that the special diving-related approach to an autopsy was both dangerous and inaccurate. This view was neither explained nor justified by documentation quoting published papers. There was surgical emphysema in the tissue of the neck, thorax, and mediastinum but no air was noted in the heart or main blood vessels using the usual autopsy technique suitable for a non-diving death. The pathologist stated, in the report presented to the Coroner that "the findings are not inconsistent with dysbarism". What this pathologist intended to convey by this statement is not clear. There was no attempt to relate the findings to the clinical picture of the events. It is not unusual for a pathologist to fail to indicate the clinical significance of findings but this was exceptionally maladroit management. Clinically this was typical of the underwater onset of cerebral arterial gas embolism (CAGE) symptoms. The lung histology showed severe oedema, congestion, and emphysema, with intra-alveolar, interseptal, and intra bronchial haemorrhages. Isolated fat emboli were noted in the capillaries.

TRAINED. EXPERIENCED. DEEP DIVER COURSE. PRACTICE BUDDY BREATHING ASCENT. BUDDY BREATHING FAILED DESPITE EFFORTS OF BUDDY. USED OCTOPUS REGUALTOR FOR PART OF ASCENT. UNDERWATER ONSET OF CAGE SYMPTOMS. AUTOPSY PATHOLOGY REPORT SHOWED INADEQUATE KNOWLEDGE.

SC89/9

The participants of this Deep Diving Course had been prevented from diving for several days by bad weather so this was the first dive of the course, a shake down dive not involving specific tests or tasks. Both the victim and his buddy were experienced divers and the dive, on a wreck lying in water 33 m deep, was uneventful. They were tasked to check that the anchor was not trapped, which they did before starting their ascent after the planned 10 minutes. After ascending about 4.5 m up the anchor line the victim tapped his buddy as if to indicate some problem. The buddy assumed this was their rate of ascent, and as this was correct she continued ascending. She then saw that the victim was drifting away from the line and signalling for her to follow. She was able to persuade him, by signs, to return. He was then about 3.6 m away from the line. On returning to his buddy he removed the regulator from his mouth and appeared to desire to buddy breath. He showed no signs of panic and gave no "low air" signal. The buddy handed over her regulator and changed to her octopus (reserve) regulator. This provided her with poorer supply of air than her primary one and she took in some water. While she was recovering from this the victim released her regulator and started to ascend without a regulator in his mouth. The buddy, breathing rhythm upset and in near panic, now ascended rapidly and called for assistance on reaching the surface.

It was only after she had been retrieved and taken into the dive boat that anyone became aware that one diver was missing following an ascent problem. He had not been seen to surface so the skipper, an instructor, descended to search for him. He found blood in the water at 15 m and followed this down to the victim. He inflated the victim's buoyancy vest (he noticed inflation was slow) and noted that the contents gauge showed there was 150 ats remaining air. The autopsy revealed the presence of a left pneumothorax, gas in the left ventricle and inferior vena cava, and air mixed with blood in many vessels over the body. There was also gas in the peritoneal cavity. There was no pre-autopsy X-ray examination of the body. Clinical pulmonary barotrauma is an unusual finding and the frank loss of blood into the water is an exceptional finding. It was clear from his evidence that the pathologist believed the reason for this massive air embolism was a too rapid ascent causing gas to be released from the tissue too rapidly. He was unaware of the different pathologies of CAGE and decompression sickness and failed to recognise hints, given him at the inquest, that he was incompletely informed on such matters.

Examination of the equipment revealed that the buddy's reserve (octopus) regulator was indeed hard to breath, while the problem which affected the victim was more complex in nature. He had recently bought a new second stage regulator and this required a higher line pressure than had his previous one. This mismatch of makes resulted in the air supply being much impaired. In addition he had a J-valve on his tank which was significantly reducing the air flow. As a consequence the filling rate of his buoyancy vest was being slowed by both the effects of depth and impaired air flow rate. This may have made him think his vest was inoperative, as he failed to inflate it, and that his air supply was near exhausted.

It was noted during testing of the equipment that the contents gauge reading fluctuated with each breath from showing half full to indicating nearly empty. If he observed this it should have alerted him to an obstruction to the flow of air from his tank.

TRAINED. EXPERIENCED. DEEP DIVE COURSE. NO RECENT DEEP DIVES. MISMATCH OF FIRST AND SECOND STAGES REDUCED AIR FLOW. J VALVE REDUCED AIR FLOW. FAILED TO DITCH WEIGHT BELT. SLOW FILLING BUOYANCY VEST AT DEPTH. NITROGEN NARCOSIS FACTOR. PANIC/ ANXIETY FACTORS. FAILED BUDDY BREATHING ASCENT. MASSIVE CAGE AND PNEUMOTHORAX. PNEUMO-PERITONEUM. HAEMOPTYSIS. BUDDY HAD PROBLEM WITH POOR OCTOPUS REGULATOR AIR SUPPLY.

SC89/10

The dive involved three divers with tanks of different capacities (72, 88 and 98 cu ft), the victim having the one with the largest capacity. Towards the time for ascent they found an anchor and, as he had the most remaining air, the victim was deputed to remain with it while the other two surfaced, one to remain "on station" to mark the position while the other swam to their boat and brought it back. This was to facilitate the recovery of their prize. However, they were unable to locate either the victim or the anchor and had to assume that a surface current had foiled their scheme. As both were now out of air they had to call for assistance with a search for the missing diver, but this search was unsuccessful. The body was found the next day. It was only after the incident that the buddies heard that he was an epileptic who was on regular medication of this condition. Although it was later stated that he had suffered no attacks for 14 years another deposition stated that he had fits if he omitted treatment for a time. He had been seen to take a tablet, presumably this medication, on the day of the fatal dive. It is nevertheless possible that he suffered a fit while alone on the sea bed. There was no mention of teeth marks on the mouthpiece but these would not occur if it fell out at the onset of symptoms.

When found, the victim's tank was empty but this cannot be taken as proof that he was indeed out of air when he died. The tank may have been low on air and emptied later. He was not wearing a buoyancy vest although he had one. He had left it in the dive boat. The weight belt was still in position, as was the rest of his equipment, when he was found.

The autopsy showed no evidence of drowning or that he had suffered an epileptic fit, according to the pathologist. The histology of the lung revealed the presence of disruption of the alveolar spaces with associated intro-alveolar haemorrhages and oedema suggestive of pulmonary barotrauma. Surgical emphysema was noted to be present in the precordial region of the chest. Despite his earlier comments, the pathologist gave as his conclusion that death was consistant with epilepsy after scuba diving.

An examination of the equipment showed that the clamp securing the mouthpiece was loose and allowed the entry of a fine spray of water with each inhalation. This was described as not sufficient to cause any distress, but the victim was not very experienced and it may have played some part in the incident.

TRAINED. SOME EXPERIENCE. TRIO DIVE GROUP. UNEQUAL SIZE OF TANKS. ATTEMPTING SALVAGE OF ANCHOR. DELIBERATE SEPARATION UNDERWATER. EPILEPTIC ON REGULAR MEDICATION. LOW AIR (PROBABLE). LOOSE CLAMP ON MOUTHPIECE SO FINE SPRAY SALT WATER INHALATED WITH EACH BREATH. PATHOLOGIST REPORTED BAROTRUAMA SIGNS, BUT IGNORED THEM IN HIS FINDINGS. PROBABLE CAGE. NO INQUEST.

SC89/11

This dive was made from rocks, the buddy swimming out first and waiting for his friend to join him. The victim had been diving for 14 years and talked about his overseas experiences so that his buddy was assured of his competence, though he had never been trained so held no certification. The buddy remained about 20 m from the rocks and watched as the victim swam out for 10-15 m then stopped and lifted up his mask. The sea was calm and conditions suitable for a safe dive. The buddy called out to him to replace his mask and look down at the king fish, but received no reply so swam over to him to find out what was the matter. He was told "I don't feel right" and the buddy observed that he looked frightened, red faced and agitated. He asked for his regulator, which was handed to him. The buddy tried to calm him and supported him as they drifted in the direction of the beach.

The buddy suggested that they swim a little further and so reach the beach but the victim declined this suggestion and looked very distressed and declared his wish to return to their point of water entry on the rocks nearby. The beach was 200 m away, the rocks far closer. The buddy towed the victim to within 3 m of the rock platform. Here the victim said he was feeling very tired so the buddy comforted him and told him to keep his mask on and the regulator in his mouth and to swim to the rocks. He assured him that he would be close behind him. There was no apparent reply but he responded in an unexpected manner, begining to swim in the opposite direction, head down and kicking with his feet. The buddy was feeling too tired to follow but shouted out to him. He saw him reach some rocks and climb onto them, so assumed that all was now right with him, so he now exited, which he found difficult because of his tiredness.

A short time later he saw his friend floating on his back 20 m away, being washed about over the rocks by the incoming tide. He managed to just grab him while standing on a small rock platform but lost his grip on the victim's buoyancy vest while unsuccessfully trying to ditch the backpack and the weight belt. The weight of the fully kitted up victim combined with the surge of the water proved too great and he lost contact with the victim. A call for assistance brought the helicopter rescue team and the victim was recovered 20 minutes later. Resuscitation attempts were unsuccessful.

The autopsy showed that the coronary vessels were healthy and almost free from atheroma for a plaque in the circumflex branch of the left coronary artery at the juntion of the proximal and middle thirds. This had a smooth surface and appeared to narrow the lumen by 40-50% but there was no evidence of infarction. There was no history of ill health.

EXPERIENCED. UNTRAINED. SURFACE ILL HEALTH SYMPTOMS AFTER WATER ENTRY. VALIANT ASSISTANCE BY BUDDY. SEPARATION FOR EXITING ONTO ROCKS NECESSARY. PROBABLE CARDIAC CAUSE DEATH. FAILED TO DITCH WEIGHT BELT. FAILED TO INFLATE BUOYANCY VEST. BUDDY FAILED TO DITCH VICTIM'S EQUIPMENT DUE TO WATER POWER.

SC89/12

This overseas visitor had been diving for several years but there is no information concerning the nature and degree of his experience. He was with a group of his compatriots on a diveboat trip to the Barrier Reef from their hotel. During the trip to the dive location the group was given a talk by the divemaster which was made against a background of chatter which required several calls for order from the divemaster. An interpreter was present but it is uncertain whether he was translating the instructions and descriptions concerning the dive. Shortly after entering the water with the group the vicitm returned to the dive boat with his buddy and complained of some problem with his regulator or mask (reports differ). The only problem identified was an over tight chest strap, which was loosened. However he then declared that he would remain on the boat and not dive, so his buddy swam back and rejoined the group. At this time someone drew the divemaster's attention to the fact that the anchor was dragging and after he had corrected this he saw a solo diver swimming away from the boat in the direction taken by the main group earlier. He assumed the victim had changed his mind about making a dive while still on the dive platform at the stern.

The victim failed to make contact with the others and it was only when a roll call was taken after the return of everyone else that his absence was noted. A helicopter made a search of the surrounding area and he was found floating near the reef. He had ditched his equipment but his backpack was found at a later date. Despite vigorous attempts to resuscitate him there was no response. This was not surprising because the pre-autopsy X-ray and CT scans revealed the presence of massive air entry into the vascular system and the tissues. There was no sign of illness.

An investigation was made by the staff following this death and several points were made of value to dive operators. There was the factor of over-confidence by the group members with consequential poor attention to the pre-dive instructions. There may have been language block to communications, despite the presence of the interpreter. An absence of "pagers" for critical personnel delayed the organsiation of the response to the "lost diver" alarm, and the dive boat Oxy-viva lacked an oxygen cylinder. It was also noticed how partiality of analysis could impair an in-house investigation close to the time of a tragedy. These comments underline the importance of maintaining a ready-response state while conducting dives.

It is naturally impossible to know what actually happened but the victim had mentioned that he did not feel well prior to the dive (but had not cancelled his scuba dive). The factor of amour-propre may have influenced his actions, a factor in many diving situations.

TRAINED. EXPERIENCE UNDOCUMENTED. SEPARATION/SOLO DIVE. DELAY IN RECOGNITION THAT HE WAS MISSING. DITCHED ALL EQUIPMENT. PULOMONARY BAROTRAUMA. CAGE. MINOR FAULT IN EQUIPMENT (OCTOPUS REGULATOR LEAKED AIR). POSSIBLY PANIC AND OUT-OF-AIR ASCENT. PRE-AUTPOPSY X-RAY AND CT CHECKS.

SC/13

The victim had been scuba diving for 3 years although he was untrained. No details of the training or experience of his two companions is recorded. They swam to a reef and there started diving for crayfish. The victim and one of the others had a catch bag and the third diver swam with his catch to whoever was the nearer. The victim was also carrying a spear gun. After 30 minutes one of the trio returned to the shore and was followed 5 minutes later by the other, leaving the victim diving alone on the reef. They saw him at the surface at this time, then lost sight of him. When he failed to reappear after a further 10 minutes they became anxious and swam out to where they had last seen him. They found him floating face down at the surface, minus his weight belt and with his backpack unbuckled and half off. The water was murky and somewhat rough at this time.

They brought him back to shore and attempted to resuscitate him but were unsuccessful. His tank still contained 100 bar when it was checked later. He was not wearing a buoyancy vest and had not called for assistance as far as his companions were aware. The reason for his drowning is not known but fatigue, the water conditions, absence of any buoyancy aid and the aborted attempt to dtich his backpack (not usually a helpful option) were probable contributary factors. It is possible that he was distracted at a critical moment by the loosened backpack after unintentionally opening its buckle.

UNTRAINED. EXPERIENCED. TRIO GROUP. SEPARATION/SOLO. CRAYFISHING. ROUGH WATER. PROBABLE SURFACE PROBLEM. SOME REMAINING AIR. DITCHED WEIGHT BELT. PARTLY LOOSE BACKPACK.

H89 1 and H89/2

This double fatality occurred on a pearl farm lease while the trays of pearl shells were being cleaned and checked. One of these divers was young and newly (scuba) trained, but the other was an experienced diver who had learned the craft from a previous employee when he first came to the job. This was considered a normal way of learning to dive. There were six divers working as teams of two on different areas of the underwater racks and the tragedy was discovered when the others met for a work break and noticed their absence and the silence of the compressor which was supplying them with air. They had been working at depths of 15-18 m and could be up to 9 m apart while working, supplied by from the compressor in their launch. The older of the two victims was acting as the instructor to the younger, who had only recently been employed. They usually worked for about 2 hours at 15 m but this might be extended by the divers, as happened this day.

There were no bubbles and the two hoses down showed that the divers were still underwater. The other divers pulled them to the surface and attempted, without success, to resuscitate them. It was later established that on the previous day the older man had complained about the bad taste of the air and had been given another compressor. But this unit had no intake pipe and he was told to take one off the compressor he was returning. This he was unable to do because it was too rusted in place to remove. The compressor was placed against the wall of the steering unit, beneath the canopy which partly covered the boat. The sea was calm and there was only a slight breeze and the exhaust fumes had been drawn into the air intake. It was noted that none of the Diving Safety Regulations were being observed and that the divers employed were untrained and usually failed to obtain treatment when they suffered from an episode of decompression sickness. This situation was well known to the authorities and permitted to continue. The District Medical Officer for the area, like his colleague in another pearl diving area in previous years, had attempted to draw attention to the need for training and better conditions but achieved nothing in the face of economic realism.

Investigations confirmed that the cause of death was carbon monoxide poisoning due to the incorrect placement of the air intake drawing the compressor's exhaust fumes into the compressor.

DOUBLE FATALITY. EXPERIENCED DIVER UNTRAINED. INEXPERIENCED DIVER RECENT SCUBA COURSE. NO SURFACE TENDER IN BOAT. BADLY MAINTAINED EQUIPMENT. INCORRECT POSITIONING OF AIR INTAKE. CARBON MONOXIDE POISONING. OFFICIAL TOLERANCE OF UNSAFE PRACTICES.

H89/3

This case also illustrates the dangers of a malpositioned air intake hose when using a compressor-supplied hookah unit. The victim was an abalone diver but the tragedy occurred while he was diving in the calm waters of a harbour doing a favour for a friend whose mooring had been disturbed during a recent storm. Indeed his compressor was in his boat on its trailer on the wharf during this dive. He made an initial dive to assess the problem, surfaced to ask for some chain and tools, then dived again. His assistant, his "sheller", was with the boat as his tender and during the time of the first descent a passer-by mentioned to him that the air hose intake was inside the boat rather than hanging over its side, so liable to suck in exhaust fumes from the compressor's engine. This was corrected. The sheller realised that it must have become displaced while the boat was removed from the water and placed on the trailer, or during the short drive onto the wharf.

The sheller became alarmed when he noticed that there were no bubbles breaking the surface. He stripped off and dived in to find out what had happened, surfacing in alarm after discovering the unconscious form of his boss. Another person pulled the victim to the surface. He was obviously beyond the reach of resuscitation and no attempts were made to perform this. The autopsy confirmed the diagnosis of carbon monixide poisoning. If the story was given correctly the air supplied to the victim for his second descent should have been "clean" and he would have been expected to escape with a headache. Either the contaminated air from the reservoir tank compromised his survival or the dose received during his first descent had a delayed, but fatal effect. This matter was not discussed at the inquest.

SOLO. ABALONE DIVER WORKING ON HARBOUR MOORING. COMPRESSOR IN BOAT ON TRAILER ON WHARF. MALPOSITIONING OF AIR HOSE INTAKE NOTED TOO LATE. CARBON MONOXIDE POISONING.

Discussion

These cases serve as a reminder that diving takes place in an environment which can be unforgiving of deviations from the rules of safe diving and where problems can rapidly progress to a fatal outcome. It is important to be aware of what may occur so that similar events can either be avoided or their effects minimised. Such is the purpose of reports such as this.

The breath-hold fatalities, which are fortunately few in number, show that post-hyperventilation blackout can kill an experienced and determined diver even in shallow water close to friends. The cardiac death may be regarded as an unavoidable risk faced by all who live, but the attempts made by his buddy to save him illustrate the vital place of a buddy in assuring survival should the course of events be not irretrievably set on a fatal outcome. The other victim was probably the recipient of a blow on his head from a powerful fish, a most unusual and "unjust" accident.

In the group of scuba divers who died, as far too many did, there are a number of findings worth consideration. Naturally the question of whether the separated and solo divers prejudiced their chances of survival by having no buddy at the critical time will continue to vex many. Where present, all the buddies performed valiantly, though from the nature of this series none were successful in saving their companions.

It was not surprising, though not really acceptable, that a group of instructors ignored all the rules of buddy diving "because it was an informal dive and there were no paying customers".

Health as a factor is of uncertain importance in the prevention of fatalities. The only diver with a history of asthma was aparently never adversely effected by it while diving, though his practice of performing a pre-dive flow-rate check indicates an incomplete understanding of the risk he ran should he inhale a fine spray of salt water. The diver with the history of epilepsy should not have been diving. It is probable that his condition was less well controlled than he admitted. Whether any of the divers where a cardiac factor was implicated would have been identified by a routine pre-dive medical is unknown but probably they would not.

Equipment problems were not in themselves necessarily fatal but they contributed to several incidents. A fine spray of sea water with every inhalation may be tolerable but it can have adverse consequences, and a high-reading contents gauge may allow a diver who budgets on too low an amount of remaining air before deciding to ascend to find himself with a serious low-air problem. One matter of signficance was the experience of the buddy who found that the secondary (octopus) regulator was hard to breath. During an emergency is not the ideal time or place to discover such an imperfection. It would seem to be a good idea to try out one's secondary regulator from time to time so as to avoid any such surprise. An important matter which was identified was the possible serious consequences of a mismatch of different makes of first and second stage oregulators if the second stage requires a higher line pressure that the first stage provides, for optimal functioning. This fact is probably unknown to many who have come to no harm but blamed the equipment they had bought. However, it should be remembered that this diver should have been dissatisfied by his demand valve's function and not accepted it, and should have regarded the wild fluctuations of the needle of his contents gauge as giving him an imperative message to ascend immediately. Possibly he did not consult his gauge so missed the warning it gave.

The number of cases where pulmonary barotrauma or air embolism (either proved or clinically probable) had occurred was a surprise and must contain a message concerning diving practices of the present day. It should be noted that it can occur without the victim reaching the surface or even closely approaching it. In this matter the author has used his reading of the evidence on occasion in preference to accepting the views of the pathologist involved in the case. There are still some pathologists who are unaware of their ignorance of diving-related causes of death, and unfortunately they are deaf to the polite advice of the police witnesses. In one instance even the performance of a "diving" autopsy did not prove to indicate an understanding of the matter in hand. As Coroners are usually obliged to follow the finding of their "expert witness, the pathologist" there can be imperfect inquest findings. There were more occasions during 1989, than in previous years, where these observations were relevant and it is for this reason a public comment is made.

Although there has been an increased incidence of cases where the Coroner has considered an inquest to be not necessary, this would be of no great moment was there not a simultaneous policy change of the coronial records of such cases not including copies of the police-supplied evidence on which the decision was based. While the primary function and responsibility of the Coroner is to examine the cases of "accidental" death, to establish or exclude the presence of some criminal acts, it is now recongised that there is an equally important function served, the investigation of such occurrences by the police acting as agents for the Coroner. The information so collected can assist the recognition of critical factors in some fatalities and thereby make it possible to devise strategies to avoid their repetition or to mitigate their consequences. Without the resource of case documentation prepared for the Coroners it would not be possible to undertake surveys such as this.

Divemasters and those who are responsible for others may find it helpful to consider the recent as well as the total experience of those in their case. They may also remember the importance of keeping an effective watch on the surface where divers may appear and require assistance. In two instances an unconscious diver was not initially noticed. In another an alert divemaster noted the unusual quietness of a diver and immediately investigated. Had the diver not suffered an inevitably fatal CAGE, his action would have been life saving.

The dangers of carbon monoxide to hookah users are well known and these three deaths underline the serious consequences which may follow the intake of exhaust fumes into the compressor. While this gas itself is odourless it is possible that a refusal to dive when the air has any odour could be a wise safety move. It is regrettable that the investigation of the double tragedy revealed that there has been no improvement apparent in the application of diving safety regulations to the pearl diving industry over several decades. The District Medical Officers at Thursday Island and Broome have commented on the situation on occasion without apparent effect. Possibly matters will change with the increased attention to the diving industry by the various Workplace Health and Safety Officers. Thoughtfully applied, such attention would be of real long term benefit to many commercial divers.

Conclusions

The dangers of post-hyperventilation blackout are again confirmed. The only way to prevent the victim drowning would be by a change in attitude on the part of such divers and the use of surface observers of them during their dives. Such an attitude change is unlikely.

Scuba divers are reminded of the importance of checking their equipment and not tolerating demand valves which let in water or regulators which are hard to breathe from. They should be profligate with their air, ascending while having sufficient remaining air for any emergency. They should seek to never place themselves in a situation where a buddy breathing ascent is the only option as this can end fatally. The practising of such ascents is therefore not advisable. The importance of an efficient surface cover, of recent diving experience, and presence of a buddy nearby should one get into trouble are all desirable propositions.

The Coronial Investigation system is of great value and information derived from it is invaluable in improving our understanding of the critical factors in diving safety.

The importance of informed pathology investigation of diving-related deaths is again stressed.

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MULTI-LEVEL RESTRICTIONS WITHIN THE US NAVY TABLES

Bruce Wienke and Dennis Graver

Abstract

Schemes for multi-level diving are employed in the commercial, scientific, and sport sectors. One approach employs back-to-back repetitive sequencing, assigning groups at the start of each multi-level dive segment based on the total bottom time (actual plus residual nitrogen) of the previous segment. At times, that method allows critical tensions, other than the controlling (repetitive) 120 minute compartment tension, to be exceeded upon surfacing. In the context of the US Navy tables, such a circumstance is suspect. But by tightening the exposure window and accounting for ascent and descent rates, such a multi-level technique can be made consistent with the permissible tension formulation of the US Navy tables. In studying this multi-level technique, we can draw a line (envelope) across the Repetitive Group Table, separating dives violating at least one critical tension at some point in the multi-level sequence from those not violating any critical tensions. Ascent and descent rates of 60 feet (18 m)/min are assumed, and the envelope also maintains tissue tensions below critical values throughout the multi-level dive. Some 16 million multi-level dives were analyzed on a CRAY supercomputer, permitting construction of the dive envelope. The standard US Navy sets of tissue half-lives and critical tensions were employed. The envelope moves non-stop time limits back a group or more in the US Navy tables, restricting the back-to-back repetitive method in the same measure. Restrictions are straightforward and simple for possible wet testing.

Introduction

To evaluate multi-level diving adequately within any set of tables, it is necessary to account for ascent and descent rates. While ascent and descent rates have small effect on in-gassing and out-gassing in slow tissue compartments, ascent and descent rates affect fast tissue compartments to a greater degree. Nitrogen build-up and elimination is measured in hypothetical compartments, whose half-lives denote time to double or halve existing levels of nitrogen.[1-15] Build-up and elimination of nitrogen is computed with well-known tissue equations (exponential rate expressions) and limit points, called critical tensions, are assigned to each compartment to control diving activity and exposure time. In multi-level diving, computed tissue tensions in any and all compartments must be maintained below their critical values. This is a more stringent constraint than just flooring the 120 minute compartment tension, the approach used in the US Navy Tables for repetitive diving.[3]

In the US Navy tables, from which many tables with reduced non-stop time limits derive, there are six compartments with 5, 10, 20, 40, 80 and 120 minute half-lives. These limit diving through limiting tensions (M-values) of 104, 88, 72, 58, 52, and 51 feet of seawater (fsw), respectively. The 5 and 10 minute compartments are fast, the 80 and 120 minute compartments are slow, and the others are often between, depending on exposure profile. Dive exposure times, depths, ascent and descent rates, affecting slow and fast compartments in a complicated manner, are virtually infinite in number, suggesting the need for both a high speed computer and meaningful representation of the results. A CRAY supercomputer addresses the first concern, while US Navy Tables provide a simple vehicle for representation of results.[16]

Controlling tissue zones

In performing multi-level analyses of the US Navy tables and derivative, tables, considering maximum allowable exposure time and minimal incremental change, it is possible to define (minimal) zones where each tissue compartment controls exposures. These incremental zones are the depths at which the 5, 10, 20, 40, 80 and 120 minute compartments control an exposure by virtue of 104, 88, 72, 58, 52 and 51 feet of seawater (fsw) critical tensions. In terms of multiples of 10 fsw, these multi-level zones are:

1	100 - 130 fsw	30-39 m	(5 minute compartment)
2	80 - 100 fsw	24-30 m	(10 minute compartment)
3	60 - 80 fsw	18-24 m	(20 minute compartment)
4	50 - 60 fsw	15-18 m	(40 minute compartment)
5	40- 50 fsw	12-15 m	(80 minute compartment)
6	0 - 40 fsw	0-12 m	(120 minute compartment)

Calculations show that is is possible to stay in each zone as long as the computed tissue tension does not exceed the critical tension for the controlling compartment, nor in all other slower compartments. Permissible times in subsequent zones are quite constant when the initial exposure (first level) is carried out to the reduced non-stop time limit for the deepest point in the zone. For the calculations, ascent and descent rates were taken at 60 ft (18 m)/minute. Bottom time for the the first level was measured from the start of the descent. Bottom times, after that, were actual times spent at that level, that is, ascent times are treated as extra exposure time and so the calculations are conservative.

TABLE 1

MULTI-LEVEL DIVE ENVELOPES WHICH NEVER VIOLATE USN M VALUES

1 100-130 fsw (30-39 m) for 8 minutes, 80-100 fsw (24-30 m) for 12 minutes, 60-80 fsw (18-24 m) for 5 minutes, 50-60 fsw (15-18 m) for 5 minutes, 40-50 fsw (12-15 m) for 10 minutes and 0-40 fsw (0-12 m) for 20 minutes

2 80-100 fsw (24-30 m) for 22 minutes, 60-80 fsw (18-24 m) for 5 minutes, 50-60 fsw (15-18 m) for 5 minutes, 40-50 fsw (12-15 m) for 10 minutes and 0-40 fsw (0-12 m) for 20 minutes

3 60-80 fsw (18-24 m) for 35 minutes, 50-60 fsw (15-18 m) for 5 minutes, 40-50 fsw (12-15 m) for 10 minutes and 0-40 fsw (0-12 m) for 20 minutes

4 50-60 fsw (15-18 m) for 55 minutes, 40-50 fsw (12-15 m) for 10 minutes and 0-40 fsw (0-12 m) for 20 minutes

5 40-50 fsw (12-15 m) for 80 minutes and 0-40 fsw (0-12 m) for 20 minutes

Zonal time limits

Maximum times in the different depth groups (the envelopes) of possible multi-level dives within the US Navy Tables, which never violate the fixed critical tensions (104, 88, 72, 58, 52 and 51 fsw) at any point during the dive or upon surfacing are summarized in Table 1. The times depend upon the depth of the first part of the dive.

Within these zonal times, the diver may hypothetically directly ascend to the surface, since tissue tensions in all compartments are always below critical values.

Some 16 million dives were analyzed on a CRAY supercomputer, in just a few minutes of actual run time. These multi-level constraints are coarse (based on worse case estimates in the whole zone), and therefore very conservative. Translated to the US Navy Tables, a line (envelope) can be drawn across the Repetitive Group Table (Figure 1), in the same manner described by Graver, separating permissible multi-level dives (no critical tensions exceeded) from non-permissible multi-level dives (one or more critical tensions exceeded).

Observations

From the above set of zonal constraints, and Figure 1, a few obvious facts emerge:

1 The deeper the initial depth, the shorter the total multi-level dive time

2 Maximum permissible multi-level dive times (total) vary between 100 and 60 minutes, depending on initial depths

3 Minimum permissible multi-level increments vary from 30 fsw to 10 fsw (9-3 m) as the depth decreases from 130 fsw to 40 fsw (39-12 m)

4 Multi-level US Navy Table dives falling within the envelope, and satisfying the above set of restrictions, never exceed critical-values, below or at the surface, in any compartments

5 Such an envelope is amenable to wet testing, given the simplicity of its structure

6 Supercomputers are great for complicated calculations.

Depth		Repetitive group designations									
m	ft	C	D	E	F	G	H	I	J	K	L
12	40	25	30	40	50	70	80	100	110	130	150
15	50	15	25	30	40	50	60	70	80	90	100
18	60	15	20	25	30	40	50	55	60		
21	70	10	15	20	30	35	40	45	50		
23	80	10	15	20	25	30	35	40			
27	90	10	12	15	20	25	30				
30	100	7	10	15	20	22	25				
33	110	5	10	13	15	20					
36	120	5	10	12	15						
39	130	5	8	10							

Figure 1. Part of the USN Repetitive Group Table with a line (the envelope) separating permissible multi-level dives, to the left of the line, from non-permissible dives.

Additionally, as an offshoot of calculations, some interesting features of the US Navy tables can be gleaned from a comparison of tissue tensions (Tables 2 and 3) computed at the reduced and US Navy non-stop time limits, again using 60 ft (18 m)/minute as the ascent rate.

1 The bottom and surfacing tension at reduced non-stop time limits never exceed the critical tensions when factoring the ascent/descent rate into calculations, just as with the multi-level calculations.

2 The bottom tensions at US Navy non-stop time limits exceed the critical tensions for a number of compartments, with the fastest compartments the worst cases when factoring the ascent/descent rate into calculations.

3 The surfacing tensions at US Navy non-stop time limits seldom exceed the critical tensions when the ascent/descent rate is included into the calculations, except in the 20, 40, and 80 minute compartments.

4 Ascent rates are crucial to using the US Navy Tables for bounce diving within the critical tension limits.

5 60 ft (18 m)/minute ascent rate off-gases fast compartments (5, 10 minutes) and in-gasses slow compartments (80, 120 minutes) with the faster compartments affected the most for bounce exposures.

Tables 2 and 3, where the units are in fsw nitrogen partial pressures (0.79 ambient pressure), will verify this.

Summary

This analysis shows that a multi-level diving technique can be made consistent with the critical tension formulation of the US Navy tables. A restrictive envelope, accounting for ascent and descent rates, can be drawn across the Repetitive Group Table to separate permissible from non-permissible multi-level dives. This should not surprise anyone using multi-level dive computers, since multi-level dive computers perform the same exercise on the fly underwater. The above is relatively simple, a set of profiles suggested for wet testing and extension of the US Navy tables.

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half-life (*min*)	depth (*fsw*)	USN limit (*min*)	tension (*fsw*)	reduced limit (*min*)	tension (*fsw*)	*M*-value (*fsw*)
5	130	10	93.1	8	86.0	104.
	120	15	99.0	12	93.6	
	110	20	98.4	15	93.5	
	100	25	94.7	22	93.4	
10	130	10	73.9	8	66.7	88.
	120	15	83.4	12	76.1	
	110	20	87.3	15	78.9	
	100	25	87.6	22	84.5	
	90	30	85.2	25	81.7	
	80	40	82.7	35	81.1	
20	130	10	55.1	8	50.0	72.
	120	15	63.2	12	57.2	
	110	20	68.2	15	60.2	
	100	25	70.6	22	67.0	
	90	30	70.9	25	66.2	
	80	40	72.4	35	69.5	
	70	50	70.7	45	68.9	
	60	60	66.8	55	65.7	
40	130	10	42.1	8	39.1	58.
	120	15	47.4	12	43.6	
	110	20	51.1	15	45.6	
	100	25	53.4	22	50.6	
	90	30	54.5	25	50.7	
	80	40	57.3	35	54.5	
	70	50	57.8	45	55.7	
	60	60	56.4	55	54.9	
	50	100	58.4	80	55.5	
80	130	10	34.5	8	32.9	52.
	120	15	37.5	12	35.4	
	110	20	39.8	15	36.6	
	100	25	41.3	22	39.7	
	90	30	42.2	25	39.8	
	80	40	44.5	35	42.5	
	70	50	45.4	45	43.8	
	60	60	45.2	55	44.0	
	50	100	48.9	80	45.7	
	40	200	52.1	130	47.4	
120	130	10	31.8	8	30.7	51.
	120	15	33.9	12	32.4	
	110	20	35.5	15	33.2	
	100	25	36.6	22	35.5	
	90	30	37.3	25	35.7	
	80	40	39.1	35	37.6	
	70	50	39.7	45	38.7	
	60	60	39.9	55	38.9	
	50	100	43.4	80	40.7	
	40	200	47.7	130	42.7	

Table 2. Comparative surfacing tensions for USN and reduced no-decompression time limits, employing 60 *fsw/min* ascent and descent rates for all excursions. Bottom time is measured from beginning of descent to start of ascent.

half-life (*min*)	depth (*fsw*)	USN limit (*min*)	tension (*fsw*)	reduced limit (*min*)	tension (*fsw*)	*M*-value (*fsw*)
5	130	10	98.6	8	88.9	104.
	120	15	107.6	12	100.0	
	110	20	106.7	15	100.5	
	100	25	102.3	22	100.8	
10	130	10	73.3	8	65.0	88.
	120	15	84.9	12	76.5	
	110	20	89.8	15	80.1	
	100	25	90.2	22	86.8	
	90	30	87.8	25	83.9	
	80	40	82.7	35	81.1	
20	130	10	53.3	8	47.9	72.
	120	15	62.5	12	56.1	
	110	20	68.1	15	59.6	
	100	25	70.9	22	67.1	
	90	30	71.4	25	66.5	
	80	40	73.1	35	70.0	
	70	50	71.4	45	69.5	
	60	60	67.4	55	66.3	
40	130	10	40.8	8	37.6	58.
	120	15	46.5	12	42.5	
	110	20	50.5	15	44.9	
	100	25	53.1	22	50.3	
	90	30	54.3	25	50.5	
	80	40	57.3	35	54.4	
	70	50	57.9	45	55.8	
	60	60	56.6	55	55.0	
	50	100	58.5	80	55.6	
80	130	10	33.7	8	32.0	52.
	120	15	36.9	12	34.7	
	110	20	39.3	15	36.0	
	100	25	41.0	22	39.3	
	90	30	42.0	25	39.5	
	80	40	44.3	35	42.3	
	70	50	45.3	45	43.7	
	60	60	45.2	55	43.9	
	50	100	48.9	80	45.7	
	40	200	52.1	130	47.4	
120	130	10	31.2	8	30.1	51.
	120	15	33.4	12	31.9	
	110	20	35.1	15	32.9	
	100	25	36.4	22	35.2	
	90	30	37.1	25	35.4	
	80	40	38.9	35	37.4	
	70	50	39.8	45	38.6	
	60	60	39.9	55	38.9	
	50	100	43.3	80	40.6	
	40	200	47.7	130	42.7	

Table 3. Comparative bottom tensions for USN and reduced no-decompression time limits, employing 60 *fsw/min* ascent and descent rates for all excursions. Bottom time is measured from beginning of descent to start of ascent.

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DEEP DIVING AND SOME EQUIPMENT LIMITATIONS

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Background

Reports of recreational diving fatalities in Australia[1] involved an analysis of the diving profile, observations of the witnesses, equipment assessment by a regulatory body, and a specialised autopsy. If the cause was not evident from the investigations, a re-enactment of the incident was often employed.

In re-enactment trials, the divers own equipment is reassembled and used, and the profile repeated by a diver of approximately the same stature, but hopefully without the same result. These techniques led to a number of breakthroughs in determining the causes of diving accidents in the Royal Australian Navy, as far back as 1967.[2]

One of the situations which has led to re-enacting dive profiles has been the observation that there is sometimes difficulty in obtaining sufficient air, either for breathing at moderate rates, or for inflating the buoyancy compensator (BC), at depths in excess of 30 m (100 feet). This is noted especially when the diver is getting "low on air".

Inadequate air supply situations have been highlighted as a significant cause of death in diving accident reviews.[1,3,4] Other workers have postulated the difficulty in obtaining adequate air through the regulator as a factor in diving accidents[5-7], and some explanations have been forthcoming.

Some of the factors which produce a limitation in the non-exhausted air supply, either to the diver, to the BC or to the alternative air supply line (octopus regulator), are obvious. These include a failure to fully open the cylinder valve, resistance or failure of the J valve (when used), and equipment malfunction problems causing regulator resistance. Laboratory investigations have demonstrated increased regulator resistance at, or near, reserve air levels, usually considered to be 35-50 bar.[6,8]

At the suggestion of one of us and while investigating a diving fatality, Wong[5] performed a series of experiments in 1988. These showed that in some circumstances, it is impossible to obtain adequate ventilation (especially under exercise conditions), while using the power inflator of the BC, once a reserve air level had been reached in the cylinder.

These problems led to a decision to observe what happens with a diver exercising (equivalent to moderately heavy breathing), at a significant depth, with the air supply on or near reserve, when using typical scuba diving equipment.

Methodology

The parameters chosen were as follows:

Depth 40 m (132 ft, 5 bar).

Cylinder pressure 35 bar (515 p.s.i.) in steel 72 cu ft (2038 litre) cylinders.

BC equivalent (a low resistance bellows volume meter) able to measure more than 10 litres i.e. sufficient to compensate for a 10 kg (22 lb) weight belt.

Six modern regulators, typically used by recreational divers, were included in the trials.

The following recordings were made at 40 m equivalent depth:

1 Time taken to inflate the 10 litre BC equivalent, while the "diver" breathed moderately heavily
2 Time taken to produce a subjective resistance to breathing, i.e. a low-on-air (LOA) situation.
3 Time taken to produce an out-of-air (OOA) situation.
4 Additional observations made by the divers and the researchers.

A separate experiment was conducted at 40 m depth to determine the speed at which the BC (volume meter) could be filled to 10 litres at different tank pressures within the reserve range (50 bar, 40 bar, and 30 bar).

As a follow-up observation, the contents pressure gauges supplied with the regulators were compared with each other as well as to a standardised pressure gauge used at the Royal Australian Navy (RAN). Volume and air consumption measurements were determined by use of the RAN standard pressure gauge, unless otherwise stated.

Six experienced armed forces divers were used, and the investigation was performed in a recompression chamber of the Royal Australian Navy, where the whole operation was under continuous, timed, video recording. Diving medics and physicians continuously monitored these chamber experiments.

The scuba diving equipment chosen was from the "up market" diving establishments who hire out this equipment. The equipment hired for the experiment included six typical regulators, pressure gauges, BCs and inflator hoses, available to any certified diver attending these establishments. The regulators would usually be hired out to experienced and certified divers, about every second weekend, and were considered by the dive operators and their clients to be in good condition. The suppliers were unaware that the equipment was to be used in experiments.

All the equipment supplied did appear to be of a remarkably high standard. The sets were modern and clean, and worked extremely well, at least on the surface.

Five of the six regulators were current models purchased less than a year before testing. All the regulators were reported to have had maintenance checks within the preceding three months.

Results

The results are given below for the time taken to inflate the BC to 10 litres when the regulator was not in use, the time taken to inflate the BC to 10 litres when a diver was breathing from the regulator, the duration of air supply at depth (starting with a cylinder pressure of 50 bar) before a LOA and OOA situation developed, the pressures at which these situations developed and the accuracy of the pressure gauges compared with the RAN gauge.

BC inflation time

Tests were performed on the equipment to determined how long it would take to supply 10 litres of air through the BC inflator line. It took 6-8 seconds for this on the surface, with a tank pressure of 30 bar.

At 5 ATA chamber pressure, when three different regulators were tested with tank pressures of 50 bar, 40 bar and 30 bar there was considerable variation in the time taken to inflate 10 litres. Although the times of inflation differed considerably between regulators, each regulator was fairly consistent. It took 20, 25 and 38 seconds to inflate from the three regulators tested when no other air outlet was in use (Table 1).

TABLE 1

TIME TO INFLATE BC TO 10 LITRES AT 40 m

Tank Pressure	50 bar	40 bar	30 bar
Regulator A	20 sec	20 sec	20 sec
Regulator B	23 sec	26 sec	26 sec
Regulator C	37 sec	39 sec	37 sec

It is evident from these results that, even with good quality, well maintained regulators, when respiration was not being performed at the same time, the time to supply 10 litres of air into the BC was between 20-40 seconds at 40 m depth. This was relatively independent of the tank pressure over the limited range tested.

Inflation time while breathing from regulator

The time to inflate the BC to 10 litres (at 5 bar) was measured while the diver breathed from the regulator (Table

TABLE 2

VOLUME ACHIEVED, TIME TAKEN AND PRESSURE REMAINING, WITH TIMES TO LOA AND OOA, WHEN BC INFLATION WAS ATTEMPTED AT 40 m DEPTH WITH A CYLINDER PRESSURE OF 50 BAR WITH THE DIVER BREATHING DEEPLY

	Litres inflated	Time taken	Remaining pressure at depth*	Time to LOA	Time to OOA	Cylinder pressure at OOA at depth*	Cylinder pressure at OOA at surface**	Minute volume of diver
Reg A	10	37 sec	20 bar	46 sec	94 sec	7 bar	10 bar	40.1 l/min
Reg B	8.2	64 sec	0 bar	64 sec	68 sec	8 bar	0 bar	54.7 l/min
Reg C	3.2	50 sec	1 bar	41 sec	50 sec	6 bar	1 bar	86.9 l/min
Reg D	0.5	41 sec	10 bar	16 sec	41 sec	12.5 bar	10 bar	84.9 l/min
Reg E	10	28 sec	20 bar	28 sec	51 sec	9 bar	5 bar	67.8 l/min
Reg F	10	24 sec	20 bar	55 sec	101 sec	8 bar	5 bar	35.3 l/min
Mean		**40.6 sec**		**41.7 sec**	**67.5 sec**	**8.4 bar**		**61.6 l/min**
Range		**24 - 64+**		**16 - 64**	**41 - 101**	**6 - 12.5**		**35.3 - 86.9**

* Scuba gauge pressure read at 40 m depth. ** Cylinder pressure read on the surface on the standardised gauge.

2).

Only three of the six regulators allowed the full 10 litre inflation prior to the divers reaching an OOA situation. The other three regulators supplied 8.2, 3 and 0.5 litres, respectively. The two worst cases occurred with the two divers who had the highest respiratory minute volumes (over 80 litres/minute at 5 bar).

While breathing at an increased respiratory minute volume, there was often inadequate air to inflate the BC. Even those that did inflate, did so slowly and took a considerable period of time (24 - 37 seconds) to supply 10 litres at this depth.

Duration of the air supply

The reports of increased resistance (a LOA hand signal) were very variable and subjective. This happened after an average of 41.6 seconds, with a 16-64 second range. A total OOA situation developed in 41-101 seconds, with an average of 67.5 seconds. Those with a higher respiratory minute volume fared worse.

Although in general it appeared that the divers with the least minute ventilation volume were able to breathe without subjective resistance for longer periods of time, the concept of "resistance to breathing" was so subjective that it appeared not to be reliable.

Judging by the observed respiratory effort, it appeared as if many of the divers were coping with quite significant resistance, without complaining. This may reflect the diver's training and personality or the effects of narcosis.

Another factor to be considered is that the inflation of the BC might be related to the resistance to breathing. In the case of regulator E, the diver signalled that he was unable to continue breathing, until he stopped inflating the BC simulator. Once he did stop this inflation, he was able to breathe for another 33 seconds.

Pressure gauge readings

The divers' tank gauges showed considerable variation at 150, 50 and 20 bar between themselves (Table 3), and with the standardised gauge after the diver had subjectively reached an OOA situation. The range of pressures observed at depth when OOA was 0-10 bar and, making allowance for this depth, the variation between the divers gauge and the standard gauge at the OOA point was 0 to 7 bar (average =

TABLE 3
TANK PRESURE GAUGE READINGS

Pressure	150 bar	50 bar	20 bar
Regulator A	152	49	17
Regulator B	142	48	16
Regulator C	142	50	22
Regulator D	135	43	19
Regulator E	140	32	20
Regulator F	150	50	23

2.4 bar).

Discussion

These experiments were performed to observe what could happen, at a depth of 40 m, when an LOA situation was encountered.

It is likely that most divers are unaware of the time needed to inflate a BC adequately at depth. This is made more difficult, and may be impossible, with moderately increased respiratory volumes, caused by exertion or anxiety.

At these depths there are many more problems that a diver may have to face. They include the effects of narcosis, increased air consumption (and therefore reduced dive duration), very significant buoyancy changes (with the compression of the wet suit making it relatively non-buoyant), reduced sensory input, and cold exposure.

The experienced divers who were used in this experiment were asked to breath deeply from the regulators under test. The varying responses can be seen in the different minute volumes of the subjects. Despite the considerable effort employed by the subjects, the result (in the form of respiratory minute volumes) was not commensurate with the apparent respiratory effort being made. The minute volumes achieved were not excessive by conventional standards for moderate exercise. Minute volumes of 62.5 litres, were considered by others[9] to be a reasonable indicator of moderate exertion.

It is also probably not appreciated that so little time is available once a LOA situation has been reached. Although we accept that 35 bar (515 psi) is a LOA situation, many divers would still believe that this is an adequate air supply for other activities, such as swimming back to a shot line, freeing an anchor, adjusting equipment, assisting a buddy, etc. Our observations show that they might have much less than a minute to perform these task before reaching a total OOA situation.

An OOA predicament can appear without an intervening LOA observation. Thus it might be worthwhile to extend the experiments with various scuba tank pressures, to determine how much the diving activity is relevant to the outflow of air from the various orifices of the first stage regulator, under differing demands. Some laboratory work on the regulator induced resistance to air flow has already been done by Egstrom.[5.] There have also been attempts, by ANSTI[9] and USN EDU[10], to compare the performance of different regulators.

What was evident from our results was that not only was there an insufficient supply of air through the regulator for breathing during sustained exertion, with a low tank pressure, but there was also an inadequate air supply available for other outlets (low pressure lines to the BC or "octopus" regulator).

From our observations, it is presumed that the higher the minute ventilation requirements, the greater the limitation of the air supply. Thus it is unlikely that subjects with low maximum breathing capacities will encounter difficulties with the same frequency as those with a higher breathing capacity or those who are exerting themselves more.

It is likely that the respiratory effort by divers is as much influenced by negative buoyancy[11,12] at depths, as by swimming speed. This might be aggravated by being deliberately overweighted (inexperienced divers, marine photographers), wearing thick wet suits at depth, problems with BC usage, or by following the advice, given by some diving operators, to exhaust the BC with ascent. The latter recommendation is made in order to overcome the hazardous effects of air expanding in the BC during ascent. It is inappropriate if there is negative buoyancy at depth and a LOA situation.

For a variety of reasons, problems that develop at great depths will be much harder for divers to solve than those occurring in shallower depths. At the greater depths, a minor problem may become magnified because of the limitations of the equipment inherent at these depths and/or the increased density of the breathing gas, as well as the physiological effects of narcosis.

One could speculate as to why these difficulties have not been widely appreciated in the past. Some experienced divers may be aware of such limitations and may well plan their dives accordingly to ensure that they do not make excessive demands on their air supply. Some divers who dive to 40 m may be unaware of the limitations imposed by scuba equipment at this depth, and may even claim that none exist if they have not personally experienced it. Some have experienced these difficulties and survived. Others have experienced the problems outlined above and died.

We believe that 40 m is an excessive dive depth, if problems such as negative buoyancy or an LOA situation develop. The consequences of diving to this depth include a very significant reduction in the ability to obtain positive buoyancy by inflation of the BC, and an inadequate air supply to the second stage regulator, be it for the diver's breathing or an octopus system. In the event of two of these three outlets being used concurrently, they would be compromised even more than they are individually.

Complete reliance should not placed on the calibration of pressure gauges, especially at low cylinder pressures. A LOA situation may develop even when the gauge implies sufficient cylinder pressure to permit adequate regulator function.

We had previously presumed that this air supply problem at depth was a rare one, contributing to only the occasional death. However it may be more widespread, and perhaps even the norm at these depths, with the scuba equipment currently in use. None of the findings should be used to denigrate any specific piece of equipment, which may be lifesaving in certain circumstances. The lesson is to understand and instruct others about the limitations of this equipment.

Conclusions

Once a LOA situation has been reached at depth, the reliable duration of the air supply for both BC inflation and breathing is very limited, and measured in seconds rather than minutes.

While engaged in tasks requiring moderate to heavy breathing (respiratory minute volumes of 35-90 litres/min) with a low tank pressure, it may take a considerable time (if it is possible at all) to inflate a BC with 10 litres of air at 40 m. This was only achieved by half of the inflator systems, when the diver was breathing from the second stage regulator. In the other half, the 10 litre volume was not achieved, at that depth, before the tank effectively ran out of air.

Problems of an inadequate air supply may exist no matter what low pressure outlet is used, a second stage regulator, buoyancy compensator inflator or octopus regulator second stage.

Recreational divers should avoid, as far as possible, exposure to depths in excess of 30 m, unless more effective equipment is available and training has been undertaken in buoyancy control and in the appreciation of equipment limitations.

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EVALUATION OF DECOMPRESSION SICKNESS INCIDENCE IN MULTI-DAY REPETITIVE DIVING FOR 77,680 SPORT DIVES

Bret Gilliam

Introduction

I conducted the logkeeping data contained here as a private project in association with my contract positions as Director of Diving Operations for Ocean Quest International (a dive/cruise company now defunct). The majority of the data is from personal review of dive boat logs, passenger records, diver interviews, recompression chamber histories and interviews with members of the professional dive staff of the ship.

I was responsible for the overall diving co-ordination of the ship including orientation of the sport dives each week, development of the computer diving program and certification course, supervision and operation of the recompression chamber facility, development of the treatment protocols, and captaining one of the ten 32 foot dive boats deployed from the ship. Additionally, as a USCG Merchant Marine Master, I served as a senior officer aboard the 457 foot cruise ship.

Background

In June of 1988, I was contacted through my consulting firm, Ocean Tech, by representatives of Ocean Quest International who wished me to undertake a variety of technical projects on their behalf. This corporation wished to enter the sport diving market with a cruise ship converted to carry 160 sport divers on diving vacations in the western Caribbean. It was anticipated that these customers would be offered as many as 17 dives in a four day period during these one week cruises.

Initially, I was asked to design a high speed, high volume air filling system, design and build the custom dive boats and consult with the ship's engineering firm on a gantry crane to launch and recover them, hire the diving and medical staff, write the operations manual, develop the training programs and refit a 60 inch multi-place, multi-lock recompression chamber for installation aboard the vessel.

One of my first concerns about the operation was the large number of dives to be offered in such as short period. This program called for four dives per day for four straight days with a night dive added in the same period. This meant that I would be facing as many as 2,720 dives by sport divers each week if the company was successful in realizing its market. To this figure would have to be added the diving schedules of the 28 professional staff members, approximately 500 additional dives. Looking at the possibility of handling over 3000 dives per week posed obvious operational cautions. To put it in perspective, many top dive resorts do not conduct that much diving in a whole year!

Addressing the issue of expected incidences of decompression sickness (DCS) left many unanswered questions. No one has ever seemed to be in agreement on the statistical incidence of DCS in sport divers. Several "experts" were polled on this issue and a wide spectrum of "qualified" responses were received. One respondent predicted 12.5 cases of DCS per week. This type of feedback was daunting to say the least.

After going forward with the design projects etc., I was asked to join the company under a consulting contract as an Executive Staff member with specific responsibilities as Director of Diving Operations.

This paper addresses the data compiled after one year of operation of the vessel. Statistics presented were recorded from March 4th 1989 to March 4th 1990. 77, 680 dives were logged during this period.

The multi-level question

Traditional sport diving resort operations typically deal with far smaller numbers of divers and rarely conduct dive operation schedules that permit up to four dives per day. Virtually all resort diving in the summer period of 1988 was conducted by "divemaster log sheets" handwritten at the dive site. Most diving was calculated using conventional tables, with the Haldane model U.S Navy tables seeing the widest use.

Given the extraordinary number of dives that this company was committed to, I wanted to provide every possible safety edge and discipline of logging dives. The basic weakness of most sport diver profile logs has been two-fold:

1 Sport divers are notoriously poor record keepers with regard to times, depths and surface intervals.

2 Several surveys and volunteer test studies have proved evidence beyond doubt that the majority of sport divers cannot calculate repetitive dive planning correctly.

One issue that came up almost immediately was whether any meaningful dive profiles could be allowed if the divers exclusively used square profile computational methods. In most circumstances, it proved unworkable for a four dive schedule in the time allowed by the ship's strict sailing routine. Therefore, the viability of "multi-level" profiling became interesting.

We felt that this method was best accomplished through the use of diving computers and eventually our program had almost 57% of sport divers utilizing these devices. (A more detailed treatment of this subject is available in my paper "One year database of sport diving exposures: comparisons of computer vs table usage" contained in the 1991 Proceedings of the International Conference on Underwater Education (IQ'91) available from NAUI).

By the fall of 1989, we made minor changes to the ship's itinerary and had modified the diving schedule to average 13 dives per week for the sport customers. However, the numbers of divers had increased dramatically during certain periods and we frequently handled in excess of 200 divers per week. We had actually got to the point where we considered 100 divers a week to be a slow period. One day in December of 1989, we did over 1000 dives!

Dives and DCS

Through the one year period March 4, 1989 to March 4, 1990, we conducted a total of 77,680 dives including customers and professional staff. Water temperature ranged from 77° F to 85° F and cannot be considered a factor in any DCS hit. Approximately 57% of our dives were done on computers, a total of 44,277. Divers' ages ranged from 9 to 72 years old. The great majority of diving was conducted with exposures of 100 feet or less. Divers were instructed to limit their diving to a maximum of 130 fsw with a 30 feet a minute ascent rate above 60 fsw; or to conform with their computer's ascent rate, whichever was more conservative. Divers averaged three dives per day although a significant number (over 20%) of customers made over 5 dives in one day if weather circumstances permitted. Reverse profiles were conducted by many divers with no adverse effects reported. Computer divers frequently admitted to reverse profiles in their personal dive scheduling. Although not sanctioned, we had knowledge of sport divers doing dives in excess of 130 fsw routinely while conducting their own dive plans. Over 40% of the computer owners questioned admitted to frequently diving below 130 fsw, several to depths in excess of 200 fsw. No hits were recorded in this group.

In conjunction with some other on-going research projects, members of the professional staff made over 600 dives to depths of 250 fsw. All were calculated by the computer (Bühlmann model) and repetitive dives were taken the same day. There were no cases of DCS on these dives.

I made over 625 dives in the one year period including 103 below 300 feet with one penetration to 452 fsw, a new air depth record. All decompression schedules for dives up to 300 feet were derived from the Dacor Mircobrain Pro Plus computer (Bühlmann model). Below that depth, I used custom propriety tables. No DCS hits were recorded.

No hits were recorded for the professional staff. Most members averaged 500 to 725 dives during the one year period. Age span was 21 to 43 years old with approximately a third of the staff being female. Dive staff members averaged between 11 and 15 dives per week.

During the year we treated seven cases of DCS for customer sport divers and none for staff. There were 12 other divers with symptom suggestive of DCS in who complete relief of symptoms was achieved by breathing 100% oxygen , by demand system, before they got to the ship. These were not recompressed. All seven patients who were treated for DCS had limited dive experience; usually less than 40 dives. Of the seven hits, 4 were women and 3 were men. All DCS hits fell in the 26 to 45 year old range. In four of the seven cases, ascent rates in excess of 60 ft/min were reported. In five of the seven cases no safety stops at 15 fsw 94.5 m) were taken. All of the DCS cases were divers using tables. DCS did not occur in any divers using dive computers correctly. The one computer user who required treatment had a decompression obligation which he ignored. This kind of stupidity obviously cannot be blamed on the device (be it tables or computer). This diver was not a graduate of our on-board multi-level computer training program. He had brought his own computer with him and declined to attend our seminar. In fact he had not even completed reading the computer manual. Of the 7 clearly symptomatic of DCS, all were successfully treated in the ship's recompression chamber with full resolution. Five of the seven divers with DCS hits were diving within the limits of their tables and can be categorized as "undeserved hits". No hits were recorded during the first two days of diving.

Incidence of DCS

With 77,680 dives in the total database and seven DCS cases, the incidence was 0.00901% or approximately one in 10,000 dives. If those with suggestive symptoms are included there were 19 cases in 77,680 dives, an incidence of 0.024459% or just over 2 in 10,000 dives.

If just the group using tables is considered, the incidence rate is 0.02%, 2 in 10,000 dives. If those with suggestive symptoms are included there were 19 cases in 33,403 dives, an incidence of 0.05688% or nearly 6 cases per 10,000 dives.

The group which used computer calculations properly had a zero (0%) incidence rate.

Discussion

Originally, the project was to keep records for a six month period. This was expanded as the diver population aboard ship increased. Of particular interest to me was the lack of DCS incidence in computer users and in the more "aggressive" experienced diver population. Precisely the diver group that we suspected was most at risk to DCS proved to be the safest. Why?

Several factors may provide partial answers. We observed the computer diver and experienced, aggressive diver groups to be far more disciplined in their regard for ascent rates, "safety" and decompression stops. They generally had better watermanship skills. Most were also more attuned to proper hydration and generally refrained from alcohol consumption during the evening periods. The decompression algorithm employed by their computers were generally more conservative than the typical Haldane U.S Navy models.

Overall, the low incidence of DCS surprised all involved in the record keeping project. Taking the whole group into perspective, and with the benefit of hindsight, I made to several observations which may account for the excellent DCS safety record.

This ship's schedule had sport diving customers board the vessel on a Sunday and depart that afternoon. Monday was an orientation day with a safety lecture required for all divers. To ensure their attendance, it was made clear that dive boat assignments would be conducted immediately following the conclusion of the one hour orientation. Fear of being left off the boat list or not being assigned to a favourite boat crew provided virtually 100% co-operation in attendance. Also, since the ship was at sea and no other diversions offered, it was relatively easy to lure divers there.

We tried to get sport divers to regard their role in our operation as a mutually co-operative one with the professional staff. We avoided any domineering or "lecture" attitudes and endeavoured to communicate safety and environmental protection information with a "we need your help to best serve you" approach that was generally well received and not resented. Many divers reported our orientation to be more instructive and less intimidating than typical resort "tirades", no matter how well intended.

Orientation served to acquaint the divers with our ship's diving operations but also had detailed general safety recommendations that we feel should be emphasized within all sport diving groups in resort settings. Of particular importance in our opinion was reinforcing disciplines of ascent rates and "safety stops" at the 15 fsw (4.5m) level for at least five minutes. By my observation, most sport divers initially have little concept of safe ascent rates even if given instruction during their entry level scuba training. Most seem to understand that slow ascents are important but fail dismally to execute proper ascents in the field.

If anything, we overstressed adherence to a 30 ft (9 m)/min ascent rate at least in the last 60 feet (18 m). The "safety stop" was further emphasized and we felt that, even if ascent rates were too rapid, instilling the "safety stop" ethic would at least slow the divers down approaching the surface. Many other resort operations stress returning to the dive boat with from 700 psi to 500 psi remaining in the diver's scuba tank. We departed from this conventional instruction and urged divers to arrive at the safety stop level with sufficient reserve for a 5 minute "hang" and then to use the remaining air for additional stop time, saving only a small reserve for the easy return to the surface. Each boat was equipped with a weighted 20 foot (6 m) PVC pipe bar hung from the dives boat's side at 15 fsw (4.5 m). This afforded an easy and comfortable platform for "safety stop" observance and the large size of the "Deco-bars" enabled as many as a dozen divers to be accommodated at once.

From observation, we found a significant number of divers did not realize that their ascent rates were excessively rapid. Typically, we would time divers in ascents ranging from 100 to 125 ft (30-37.5 m)/min and upon questioning, the diver would express surprise and voice the opinion that they thought they were conforming to 60 (18 m) or even 30 ft (9 m)/min rates. Most divers simply find these recommended rates to be ridiculously slow (from their perspective) and only through continued education and patient explanation will the disciplines of proper ascents be applied. Most important however, is to establish a non-confrontational relationship with sport divers so that a willingness to learn will evolve. Our staff was trained to emphasize all safety recommendations daily on the dive boats and to observe divers in the water. Tactful suggestions and critique were to be offered in areas where divers could improve technique. We had great success with these methods and felt reasonably confident that 90% of our customers were complying.

Due to the temptation of being aboard a cruise ship where the availability of alcohol was ever-present we felt obliged to remind divers that alcohol consumption the night before a heavy diving day was ill-advised. Surprisingly, we met with few problems from our diver population in this regard. Most got their "partying" out of their systems on the Sunday night departure from the U.S. port and refrained from or adopted modest alcohol attitudes until the four days of diving were completed. Staff example went a long way to promoting compliance. Our professional divers generally observed a voluntary curfew on evenings before diving of 11:00 p.m. Since most diving would begin as early as 8:30 a.m., we encouraged a good night's rest in customers and staff. For staff, it was a necessity due to their heavy work and diving schedule.

Another strong emphasis was placed on proper hydration of divers. We recommended consumption of non-carbonated beverages; but suggested staying away from orange, tomato and grapefruit juices due to their tendency to precipitate seasickness in many divers. Each boat was supplied with large containers of cold fresh water and unsweetened apple juice (the latter affectionately known as "Emmerman" due to this individual's advocacy in his many articles on hydration). Each boat crew pushed consumption of these fluids between dives during the course of the diving day.

We also included a detailed segment on recognition of DCS symptoms. Since we had a fully staffed and functional recompression chamber aboard we made our guests aware of its location and that we used it not only for training programs but we expected to use it for treatments as they presented.

Denial of symptoms and subsequent delay of treatment has always been major problems in sport divers. We tried to make it clear that DCS has a certain statistical inevitability and that no stigma or "blame" would be placed on an individual who reported problems. We let our divers know that each boat captain was trained in diver first aid and each boat was equipped with O_2 units equipped with demand regulators to insure delivery of 100% O_2 if needed. There was no charge for the O_2 or for evaluation by the author and diver medical technician. In fact, we did not charge for tests of pressure or treatments.

As a result of the orientation sessions, we overcame the traditional reluctance to report symptoms and in many cases found ourselves burdened with evaluations of numerous muscle strains etc. not related to DCS. But at least, our divers were enthusiastically coming forward to report even slight perceived symptoms. We would always prefer to err on the side of caution and the few cases of obvious non-DCS injury were welcome in preference to the denial attitudes so frequently prevalent in the past.

Chamber facility

We were lucky to acquire a 60" PVHO classed recompression chamber which we completely refitted for use on the ship. We purchased the chamber and essentially discarded everything but the pressure vessel. Two staff members then replaced all fittings, installed a new radio communications system including two sound-powered phone handsets, 6 new BIBS (built in breathing system) masks with overboard dumps for O_2 delivery, two new O_2 analyzers, a fire suppression system, 50/50 Nitrox therapy gas, new gauges and timing devices. All ports were removed and replaced along with all hatch o-rings. The entire unit was cleaned and repainted white with all gas lines colour coded.

When completed, the chamber was state-of-the-art and Dick Rutkowski of Hyperbarics International was brought in to examine and certify its readiness. Rutkowski was also used on three occasions to conduct specialized training for chamber operators and technicians with his well known courses.

I and two other staff members had extensive prior chamber operation experience from military and commercial backgrounds and we had one DMT graduate from Oceaneering. Training runs and protocol discussions were conducted weekly with the majority of the dive staff participating in various roles in the chamber's operation. This provided a continuing education process and ensured operational readiness of all systems and staff. Periodic test cases were presented by passenger volunteers coached to appear with DCS symptoms to present staff with actual "real life" scenarios to react to.

Additionally, we developed the first sport diver certification program in Accident Management /Introduction to Recompression Chambers. I wrote the course with the intent of involving sport divers in an intensive hands-on learning situation that included field evaluation of diver patients, O_2 administration, patient handling and transport, record keeping and actual dives in the chamber including breathing from the BIBS with dives to 60 feet.

This program was approved by both PADI and NAUI and hundreds of divers participated in it during 1989 and 1990. This program was scheduled for a travel day at sea after conclusion of the diving program on Friday afternoon. Most divers expressed the opinion that this course made them far more aware of pre-disposing factors and health conditions to DCS and AGE, and appreciated the in-depth accident management modules especially with O_2.

Our protocols called for very aggressive diver treatment. Divers reporting symptoms were placed on 100% O_2 by demand mask and immediately transported to the ship for evaluation by the author or DMT. Significantly, we had approximately 12 cases of symptomatic DCS that relieved completely during the 100% O_2 breathing period during transit from dive site to ship. As is standard practice in the commercial diving industry, we have not counted these cases as confirmed DCS incidents since they were not confirmed through a recompression test of pressure. However, in my opinion, the importance of 100% O_2 by demand mask cannot be over-emphasized.

With regard to treatment tables, it is my firm opinion that use of U.S Navy table 5 is not appropriate in sport diver DCS presentations. Virtually all sport diving DCS cases I have treated in my career will show Type II symptoms upon close examination. In many cases, Type I symptoms present and the patient may complain vigorously of muscular/ skeletal "pain only" symptoms only to discover further evidence of Type II numbness etc. once the "pain only" symptoms have abated. The masking of Type II DCS has led to improper and insufficient treatment on table 5 when a table 6 with extensions may have been called for.

We aggressively treated all presentations with table 6 and used table 5's for clean-ups when initial treatment did not produce full resolution. Under these protocols we had complete resolutions in all patients.

It should be noted that the data base presented here only considers the ship's sport diver population. Other patients presented for treatment from time to time from resorts, commercial divers engaged in fishing using scuba etc. Case 4 is included because it is of interest due to its extreme repetitive exposure.

Selected case reports

Case 1

The patient presented with numbness and tingling on his right side localized to the foot, ankle, wrist and forearm. Skin mottling was also noted. Numbness etc. had become progressively worse since making 2 dives in Cozumel with profiles of 60 fsw (18 m)for 32 minutes with an approximate 1 hour surface interval followed by second dive to 48 fsw (14.5 m) for 25 minutes. He was in fourth day of a repetitive diving vacation, with over 24 hours since the previous day's diving. The dives were unremarkable with normal ascents and no work. Water was 79° F with excellent visibility although a moderate current was prevalent in both dives, as is typical for Cozumel diving conditions. Symptoms developed within one hour of surfacing from the second dive but they were not reported until approximately eight hours later as they progressively worsened. He did not believe he could be bent.

A test of pressure was performed and after a 20 minute breathing period on O_2 by BIBS mask at 60 fsw in chamber the patient reported complete relief. A standard treatment table 6 was followed with complete resolution.

He was calculating his dives using standard USN tables. He was a 43 year old male with no obvious physical detriments; diving experience included frequent sport diving in the four years since he was certificated.

Case 2

The patient presented with shoulder pain after making two dives in Cozumel with profiles: 76 fsw (23 m) for 25 minutes; approximately 1 hour ten minutes surface interval with second dive to 58 fsw (17.6 m) for 32 minutes. The diving conditions were ideal, with the typical Cozumel current. Symptoms developed approximately 2 hours after surfacing from the second dive but were not reported until nine hours later when pain had progressively worsened.

A test of pressure was performed and after a 12 minute period breathing O_2 by BIBS mask at 60 fsw (18 m) in the chamber she reported complete relief. A standard table 6 was followed with complete resolution.

She was a 44 year old female, overweight by approximately 35 pounds (16 kg) and in generally poor physical condition. She reported a previous injury to the shoulder where the initial symptoms developed.

She had infrequent diving experience although certificated for five years. She was calculating dives using PADI RDP tables.Her dive buddy reported poor ascent technique and poor buoyancy control throughout both dives.

Case 3

This patient presented initially with mild tingling in both hands. He was held two hours for observation and upon re-examination was found to have marked progression of tingling and numbness and fatigue. Also his disposition had altered and he was becoming lethargic and unstable while walking and had difficulty maintaining normal balance.

He had made a total of nine dives all within USN table limits in the three previous days. He had a 20 hour interval before resuming diving on the fourth day. He dived to 51 fsw (15.5 m) for 58 minutes, 67 fsw (20.3 m) for 43 minutes and 95 fsw (28.8 m) for 46 minutes. Neither he nor his buddy could provide accurate surface interval information. They were using profiles supposedly obtained from USN tables. He had declined to dive under the supervision of a ship's divemaster. Symptoms developed within one hour of surfacing and he immediately reported to the ship's diving officer upon returning from the Mexican Cozumel diving boat. This was approximately two hours after the last dive.

He was given a test of pressure and reported complete relief after 10 minutes of O_2 by BIBS mask at 60 fsw in chamber. A standard table 6 was followed with complete resolution.

Case 4

This man presented with severe symptoms including inability to walk, bilateral paraesthesia, incoherent speech. He collapsed during examination. He was immediately recompressed to 60 fsw (18 m) in the chamber and put on O_2 by BIBS mask with no relief. Compression was continued to 100 fsw (30 m) on air where relief was reported of most symptoms. He was decompressed to 60 fsw (18 m) and a standard table 6 was followed with complete relief.

A history was obtained of his previous day's diving. The patient was a male Mosquito Coast Indian professionally employed as a lobster diver, using scuba gear, in the Bay Islands of Honduras. He made between 10 and 12 dives in a nine hour period to average depths of 125 fsw (37.5 m) or greater. The procedure was to dive until his tank was exhausted and then make a free ascent. Repetitive dives were performed non-stop in this manner until the diver began to feel numbness and tingling in his right arm and shoulder. Another dive was made and these symptoms were relieved underwater and he continued diving until he ran out of air and ascended rapidly. Almost immediately upon surfacing he noticed pain in his legs and then progressive numbness and tingling. His boat was over 12 hours from Guanaja (Bay Islands) and on the trip in, he consumed a large quantity of a native alcoholic drink and ultimately passed out.

His diving buddies brought him to the Ocean Quest when they heard that there were divers on board who "knew how to fix divers when they get twisted". The patient was paddled out to the ship in a dug-out canoe by his companions who related his profiles.

Although he was completely relieved following a table 6, he was advised to remain on board the ship for transfer to Roatan's chamber facility for observation for recurrent symptoms. At this point the patient became highly agitated and insisted on leaving the ship. When attempts were made to restrain him in order to have his companion better explain (as interpreters) the seriousness of his condition, he attempted to jump over the side into the water and swim to shore. I explained that he could leave at any time and urged him not to return to diving for at least a week and to obtain a medical examination. He chose to depart immediately by canoe with his companions. Apparently his immigration status was questionable and had prompted his anxiety about transfer to Roatan.

I learnt later that he resumed diving two days later and I understand that he still continues to dive, with no apparent further problems.

Conclusions

This data would suggest that the incidence of DCS in sport divers is far lower than that was originally expected.

In this diver population certain factors may have contributed to their safety record. These include aggressive counselling, through the orientation sessions, about proper hydration, rest and low alcohol usage. Of primary importance was the constant stressing of slow ascent rates and "safety stops". Additionally, professional diver staff members were trained to observe and tactfully correct bad diving habits and to assist with the review of dive planning and repetitive table use.

Also, the importance of dive computer use in contributing to more accurate dive profiling and use of more conservative decompression algorithms clearly played an important role in limiting DCS incidence rates. The fact that the group using dive computers properly made 44,277 dives with zero incidence of DCS must be considered significant.

Interestingly, the most aggressive group of divers making the deeper and largest number of repetitive dives had the best overall safety record against all conventional wisdom. This would seem to be due to the experienced divers' greater discipline with regard to ascent rates, observance of "safety stops" for long hangs, proper hydration practices, better knowledge of table and/or computer use, and overall better diving and watermanship skills.

Further, aggressive use in the dive boats of O_2 administration by demand mask may well have relieved other unconfirmed DCS hits. On-site chamber treatments that offered tests of pressure and evaluations usually within two hours on symptom onset certainly contributed to the 100% resolution rate for patients. Finally, the encouragement of prompt symptom reporting with no associated peer or professional "blame" or stigma attached is refreshing in a sport diver community that has historically been infamous for symptom denial.

In the case of the professional dive staff some validity to the hypothesis of "adaptation" must be given serious consideration. These individuals dived aggressively for four straight days, then received three days off before resuming that schedule. Most made between 500 and 725 dives in the one year period. Many routinely performed diving in the 250 fsw range or greater with subsequent repetitive dives and yet no DCS hits were recorded in any staff. The "multi-day skip" suggestion may well be validated later.

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Bret C Gilliam is the President of Ocean Tech. The address of Ocean Tech is 3098 Mere Point Road Brunswick, MAINE, 04011, U.S.A. Telephone 207-442-0998 and fax 207-442-9042.

Mr Gilliam was Vice President of Diving Operations for Ocean Quest International and Senior Officer aboard their diving cruise ship Ocean Quest. He is author of Deep Diving: An Advanced Guide to Physiology, Procedure and Systems *(published December 1991) and of* Mixed Gas: The Ultimate Challenge for Technical Diving *(scheduled for release in May 1992).*

SPUMS NOTICES

SPUMS STATEMENT ON DIABETES

Introduction

Generalization is always difficult when giving advice about a specific medical condition, such as diabetes mellitus, and its relation to diving. Each applicant requires individual assessment with regard to the disease, its severity and control, and how well the patient understands both the disease process and the diving environment.

The role of the physician for the recreational diver is that of adviser to the patient, his family and possibly his fellow divers, and to provide information on the risks that the pathological process may represent in the underwater environment. Should such applicants then choose to ignore the advice given, the advising physician should not be subsequently liable.

In commercial diving, fitness standards are largely "black and white". Regulations limit the options for a physician with respect to certifying an individual as fit to perform a specific task. In addition, many commercial diving companies have their own stringent fitness standards as a precondition to employment and in such circumstances there is no place for a diabetic in the commercial diving field.

Diabetes mellitus

Diabetes mellitus is a common endocrine disease resulting from a deficiency of or insensitivity to insulin. The disease spectrum is wide and ranges from the young child dependent on frequent doses of exogenous insulin to the elderly patient whose blood glucose level can be controlled by diet alone. Between these extremes is large group of patients controlled by diet and oral hypoglycaemic agents but who may sometimes require insulin for glucose control when under severe stress.

It is often forgotten that many diving trips are preceded by a passage in an open boat. The diabetic who takes his insulin prior to departure and then is either unable to eat or suffers from repeated vomiting as a result of sea sickness is especially prone to hypoglycaemia. The stress of a dive added to this unstable state may well precipitate a hypoglycaemic crisis. In addition, the travel and diving schedule may interfere with the normal eating timetable so essential for the maintenance of stability in diabetics.

Every physician who has been present at an insulin induced hyopglycaemic reaction can attest to the rapidity at which symptoms appear and the speed with which judgement is impaired.[1] Rapid loss of consciousness occurs in a significant number of hypoglycaemic diabetic patients. The normal symptoms of impending hypoglycaemia; agitation, sweating, circumoral paraesthesia, palpitations and confusion are all effectively masked by immersion and the normal anxiety of the novice diver. In the more experienced diver, the narcotic effects of nitrogen may well disguise these symptoms further.

During a dive, any loss of consciousness usually results in the regulator being dislodged from the mouth so that the victim either aspirates water or has laryngeal spasm and becomes apnoeic. Unless the buddy is immediately to hand, the victim will drown. Such a situation necessitates an emergency ascent with the attendant problems of gas expansion (according to Boyle's Law) resulting in barotrauma to the lungs. If there is a significant nitrogen load, the missed decompression schedule will put both victim and rescuer at risk of decompression illness.

Physicians who are sympathetic to their diabetic patient's attempts to gain recreational diving experience often quote examples of world class athletes who have diabetes.[2] Such physicians either forget or are unaware that the diving environment is totally different from the athletic field or tennis court, in its density, the rate in which pressure changes occur, and the distance from skilled medical assistance. Although most diving is safe and quite leisurely, the need for unplanned, severe, sustained exercise is always present. On the athletic field, the blood glucose level can be easily maintained with drinks and nutritional supplements. The carriage and consumption of these items in the course of a dive is not as readily achieved.

A diabetic hypoglycaemic reaction is most likely to occur towards the end of a dive at which time it will be associated with hypothermia, high nitrogen load, dehydration and fatigue, all of which predispose to and may exacerbate the effects of decompression illness.

Complications

The end organ complications of diabetes predominantly affect the cardiovascular and neurological systems. There is a premature onset of generalised arterial disease in diabetic patients which has wide ranging effects on the myocardium, the kidney and the peripheral circulation. Myocardial infarction occurs earlier in diabetics and may be more severe as it is often associated with arrhythmias or cardiogenic shock. Such infarcts may be painless, especially when the victim is immersed as this eliminates the orthostatic hypotension associated with pump failure.

Peripheral vascular disease which interferes with the circulation to the limbs is profoundly affected by the hypothermia of immersion. It may also affect the rate of gas exchange in the tissues making the diver more liable to decompression illness.

The neurological complications of diabetes which may affect candidates wishing to dive include polyneuropathy, amyotrophy and autonomic neuropathy. Such neuropathies result in muscle wasting, glove-like anaesthesia of the limbs and a loss of deep tendon reflexes. These may be a source of confusion to any physician if the patient subsequently presents for recompression therapy. Autonomic neuropathy may result in bladder dysfunction and urinary retention, disturbed temperature regulation, postural hypotension and cardiac arrhythmias in times of stress. Loss of afferent supply from the myocardium may be a reason why diabetic patients are subject to "silent" or pain free myocardial infarcts.

In the vascular system, free gas not only obstructs smaller vessels and destroys endothelial surfactant resulting in loss of integrity of the intimal layer, but there is also a surface effect of the bubbles which causes denaturation of protein, increased platelet and white blood cell adhesiveness and stimulation of the clotting cascade. A study reported Halushka et. al. showed that, in diabetics, platelet agglutination occurred more rapidly in response to ADP, adrenalin and collagen as a result of increased activity of the platelet prostaglandin synthetase system.[3]

Fibrin and platelet deposition around a bubble stabilise a bubble so that it is more difficult to remove by recompression. A diver with a significant nitrogen load who performs a too-rapid ascent may suffer from bubbles of gas forming in the tissues and venous capillaries. This decompression illness is associated with intravascular changes in protein, platelets and extravasation of fluid into the extracellular space. It follows therefore that a diabetic diver is almost certainly more likely to suffer from decompression illness than a healthy diver in the same circumstances.

This liability to decompression illness is compounded by the earlier onset of obliterative vascular disease in diabetic patients. These vascular changes are independent of the quality of control of the blood glucose level. The pathology affects all levels of the vascular tree and, potentially, interferes with the kinetics of gas exchange and slows the elimination of nitrogen from peripheral tissues.

In all classes of diabetic patient the end organ disease is often more severe than the symptoms suggest and is unrelated to the level of control of the diabetes. The non insulin dependent diabetic is typically obese, middle aged and unfit. The diving physician can usually eliminate such a candidate on the grounds of medical problems other than just diabetes.

Summary

Although most recreational diving is safe, uneventful and conducted at a leisurely pace there are occasions when it becomes exceedingly stressful and there is a need for unplanned, severe, sustained exercise.[4] A diabetic whose blood sugar is controlled either with insulin or other oral agents would be incapable of maintaining such an exercise level and should be guided into less exacting pursuits.

The insulin dependent diabetic is prone to hypothermia, hypoglycaemia resulting in loss of consciousness and decompression illness and consequently should be advised against diving.

Diabetics controlled by oral hypoglycaemics are usually obese, unfit and are unable to maintain an acceptable exercise level.

The diabetic controlled on diabetic controlled on diet alone may be permitted to dive if he demonstrates adequate cardiorespiratory fitness and all other criteria tested at the diving medical are found to be within normal limits.

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David Davies, FANZCA, DipDHM,
Education Officer SPUMS

MINUTES OF COMMITTEE TELECONFERENCE

held at 1000 Daylight Saving Time
on Sunday, 24th November 1991

Apologies

Dr A Slark

Present

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

1 **Minutes of Previous Meeting**

The version to be published in SPUMS J. 21/4 was accepted as a true record.

2. Business Arising from the Minutes

2.1 PORT DOUGLAS MEETING

The program distributed by Allways (to be published in SPUMS J 21/4) is not final program. Dr Williamson will circulate the penultimate version to the Executive in about 6 weeks.

Some criticism of the pre- and post-conference diving options proposed by Allways was noted, both as to limited choices and number of dives offered.

Because of the difficulty in getting Geoff Skinner to return calls, Dr J Robinson was appointed to contact him on behalf of the Committee to review these arrangements.

Dr Barry felt that the large number of Registrants this year should enable the registration fee to cover the speakers' costs. Dr Robinson is to ask Allways for a Conference Budget.

It was decided that the chairpersons at future Annual Scientific Meetings must be SPUMS members. With non-medical topics it was considered that if a non-member, with special knowledge of the topic, could conduct the question and answer session more efficiently than the SPUMS member appointed chairperson, the non-member could be appointed as co-chairperson

2.2 PALAU MEETING

Dr David Elliott has accepted our invitation and will supply a draft of his program in due course

2.3 PNG MEETING

Dr Gorman will assess conference capability when he visits next year.

2.4 ANZHMG

A meeting will be held on December 2nd at the Alfred Hospital, Melbourne. The morning session will be a Business Meeting. The afternoon session will be clinical with discussions on the Alfred Hospital experience in treating osteomyelitis, and gas gangrene, and the 1991 view of AGE. In the evening there will be a dinner.

2.5 DIVE COMPUTERS

Dr Acott is doing background reading.

2.6 OXYGEN CYLINDERS ON DIVE BOATS

Dr Robinson is to pursue this matter with Allways.

2.7. SAFETY SAUSAGES

ALLWAYS has paid.

2.8 DIVING AND DIABETES

Dr Davies is collating some material at present.

3 North American Chapter

Ray Rogers has asked us to finance a poster exhibition relating to the activities and aims of SPUMS at the Diving Equipment Manufacture Association (DEMA) exhibition. This was agreed to.

The North American Chapter is to provide annual financial reports.

4 Diving Doctors list

This list is updated from time to time. People doing the Royal Adelaide Hospital courses are given SPUMS membership forms and may join. There was discussion as regarding whether to publish a New Zealand list in our Journal and how best to ascertain those doctors who have done a properly accredited course.

Dr Knight is to send a list of NZ members to Dr Gorman who will check these against lists of those who have done Underwater Medicine courses at Christchurch and Auckland. Non-members will then be sent SPUMS application forms. The amended list will then be published in our Journal.

5 Standards Australia Meetings

5.1 RECREATIONAL DIVING

Dr Knight reported that Committee CS/83 had approved the final draft of a standard for the Training and Certification of Recreational Divers Part 1: Minimum Entry-Level Scuba Diving. The SPUMS medical, with minor modifications, had been accepted including a compulsory medical examination, but the requirement that the medical be conducted by a doctor with training in underwater medicine was not accepted. Only SPUMS and the Seamen's Union voted for such training to be mandatory. The AMA did not support our stand. Dr Knight's report will be published in SPUMS J 20/4.

5.2 WORKSAFE AUSTRALIA

A meeting of Committee SF/17 (occupational diving), on which SPUMS is now represented, was addressed on the forthcoming Worksafe Australia diving standard which will cover all diving. The basic concept is that of a duty of care both by an employer to employee and instructor to student. Dr Knight's report will be published in SPUMS J 20/4.

5.3 FURTHER ACTION

It was decided that the SPUMS policy, that only doctors with the appropriate training should do diving medicals, and the reasons for it must be pursued. Dr Gorman will write to the AMA, at Federal and State level, expressing our concern at their vote at the CS/83 meeting. The SPUMS diving medical will be sent out, as a supplement, with SPUMS J 22/1.

6 Treasurer's report

Dr Barry said that only about 50% of NZ members were financial. Converting NZ cheques cost us $8 per transaction. It was resolved that an ANZ bank account be opened with Credit Card facilities. This facility will be included on our subscription form, this should reduce NZ non-payers and reduce costs. This is to be organised by the Treasurer. Dr Barry announced his decision to resign as Treasurer.

7 Diploma of Diving and Hyperbaric Medicine

The Board of Censors have awarded the DDHM to Drs Vic Callanan and Tom Fallowfield.

8 Correspondence

Letters from Dr N Cooper have led to the UK tax authorities accepting subscription to SPUMS as tax deductible and to recognition of the DDHM as post-graduate training time by the UK Faculty of Occupational Medicine. A letter has been sent thanking him for his efforts.

9. Other business

9.1 Dr Gorman will supply an Editorial on "Mixed Gas Diving to our Journal.

9.2 A letter to be sent to Peter Bennett making him a full member.

The next Meeting will be on 16 February 1992 at 1000 Daylight Saving Time

SPUMS ANNUAL SCIENTIFIC MEETING
Raddison Royal Palms Hotel
PORT DOUGLAS 30th MAY-6th JUNE 1992

Australia's "Wonder of the World"
The Great Barrier Reef (GBR)

Saturday 30th May

1600-1615 hrs **Welcome and opening ceremony**

Session 1 The Reef geographic setting (I)

1615-1630
Significance to the world of the GBR.
Dr Joe Baker, OBE, FTS, PhD, Director*,
1635-1640 Questions and discussion
1640-1705
Geological origins of the GBR.
Dr D Kinsey, PhD*
1705-1715 Questions and discussion
1715-1735
GBR morphology and physiology.
Dr J ("Charlie") Veron, PhD*
1735-1745 Questions and discussion

Session 2 The Reef geographic setting (II)

1800-1820
Oceanography of the GBR.
Dr E Wolanski, PhD*
1820-1830 Questions and discussion
1830-1855
Evolution of the coral reefs, the Greenhouse scenario.
Dr D Kinsey*
1855-1910 Questions and discussion
1910-1930
Mangroves and the GBR.
Speaker to be announced
1930-2000 Question & discussion

Sunday 31st May

Session 3 The Reef Ecosystem (I)

0900-0920
Reef coral biology.
Dr J Oliver, PhD*
0920-0930 Questions& discussion
0930-0950
Coral taxonomy.
Dr J Veron, PhD*
0950-1000 Questions & discussion
1000-1020
Coral reproduction.
Dr R Babcock, PhD*
1020-1030 Questions & discussion

Session 4 The Reef Ecosystem (II)

1100-1120
Reef algae: green, brown, red.
Dr Ed Drew, PhD*
1120-1130 Questions & discussion
1130-1150
Reef fishes.
Dr D Williams, PhD*
1150-1200 Questions & discussion
1200-1220
Plankton.
Mr J Carleton, MSc*
1220-1250 Questions & discussion

Session 5 Reef structures and functioning (I)

1400-1420
Zonation in the GBR.
Dr T Done, PhD*
1420-1430 Questions & discussion
1430-1450
Organic production - primary producers.
Dr Ed Drew, PhD*
1450-1500 Questions & discussion

1500-1525
Reef trophodynamics; detritus chain; consumer chain.
Dr Michel Pichon, PhD, Deputy Director*
1525-1535 Questions & discussion

Session 6 Reef structures and functioning (II)
1605-1625
Ecosystem metabolism: autotrophy or heterotropy.
Dr Michel Pichon, PhD*
1625-1635 Questions & discussion
1635-1700
Nutrient fluxes.
Dr M Furnas, PhD, Dr D Alongi, PhD and Dr E Drew, PhD*
1700-1710 Questions & discussion
1710-1730
Carbon budgets: bioconstruction and destruction.
Dr M Pichon, PhD*
1730-1800 Questions & discussion

Monday 1st June

Symposium on board MS "Quicksilver"
Session 7 The Reef and man (I)
20 minutes
Human impacts.
Dr Michel Pichon, PhD*
10 minutes Questions & discussion
20 minutes
Protection and conservation of the Reef resource: the marine park concept.
Dr D Kinsey, PhD*
10 minutes Questions & discussion
20 minutes
The GBR marine park; zoning plans and management strategies.
Speaker to be announced
Queensland National Parks and Wildlife
10 minutes Questions & discussion

Tuesday 2nd June

Symposium on board MS "Quicksilver"
Session 8 The Reef and man (II)
20 minutes
The Reef as a tourist attraction.
Dr Alastair Birtles, PhD
10 minutes Questions & discussion
20 minutes
Coral injuries on the GBR.
Professor Vic Callanan,FANZCA, DipDHM
Director of Anaesthesia and Intensive Care
Townsville General Hospital.
10 minutes Questions & discussion
20 minutes
The Crown-of-Thorns starfish.
Dr Peter Moran, PhD*
10 minutes Questions & discussion

Wednesday 3rd June

Session 9 The Reef and man (III)
0900-0925
Reef fisheries.
Drs D Williams, PhD and P Doherty, PhD*
0925-0935
Questions & discussion
0935-1000
Chemicals and drugs.
Drs P Murphy, PhD and W Dunlap, PhD*
1000-1010
Questions & discussion
1010-1035
Creating a captive coral reef ecosystem.
Dr Martin Jones, PhD, Senior Curator
Great Barrier Reef Aquarium, Townsville.
1035-1040
Questions & discussion

Session 10 The medical reef (I)
1110-1130
Sea snakes of the GBR region.
Dr Chris Acott, FANZCA, DipDHM
Hyperbaric MedicineUnit
Royal Adelaide Hospital, South Australia
1130-1140
Questions & discussion
1140-1200
The amazing nematocyst.
Dr Jacquie Rifkin
Consultant Zoologist, Brisbane
1200-1210
Ciguatera poisoning.
Dr Geoffrey King, MB, BS, Director
Royal Flying Doctor Service, Cairns
1230-1245 Questions & discussion

Session 11 The medical reef (II)
1345-1405
The work of the International Consortium for Jellyfish Stings.
1405-1415 Questions & discussion
1415-1435
Jellyfish of the GBR region.
Dr Robert Hartwick, PhD
James Cook University of North Queensland
1435-1445 Questions & discussion
1445-1505
Aquatic world awareness, responsibility and education in diver training and tourism.
Mr Drew Richardson, Vice-President
Training and Education, PADI International.
1505-1515 Questions & discussion

Session 12
1600-1645
Annual General Meeting of SPUMS

1645-11715

Inaugural Annual General Meeting of The Australian and New Zealand Hyperbaric Medicine Group (ANZHMG) together with the ANZ Hyperbaric Technicians and Nurses Association (HTNA)

1715-1725
Hyperbaric chamber design
Dr Peter McCartney, MMed (Anaes), DipDHM
Director of Hyperbaric Medicine
Royal Hobart Hospital
1725-1730 Questions & discussion
1730-1740
CO off-gassing during HBO therapy
Mr Peter Langston, Mr Robert Ramsay, Drs John Fry, John Williamson and John Russell
Royal Adelaide Hospital
1740-1745 Questions & discussion
1745-1755
HBO therapy and vasculitis
Dr Harry Oxer, FCA, FANZCA, DipDHM
Director, Hyperbaric Medicine, Fremantle Hospital
1755-1800 Questions & discussion

Thursday 4th June

Symposium on board MS "Quicksilver"

Session 13 The diver's reef

40 minutes
Diving and the law.
Dr E Drew, PhD*
20 minutes Questions & discussion
20 minutes
Diving and the coral.
Mr Colin Hodson, Director, "The Dive Bell"
Commercial Diver Training Academy, Townsville
10 minutes Questions & discussion

Friday 5th June

Session 14 Diving safety on the GBR (I)

0830-0845
Diving safety - where are we going ?
Dr John Knight, FANZCA, FACOM, DipDHM
Editor, SPUMS Journal
0845-0850
Australia-wide communication and diving safety.
Dr John Williamson, FANZCA, DipDHM
Director of Hyperbaric Medicine
Royal Adelaide Hospital, South Australia
0850-0900 Questions & discussion
0900-0920
Queensland legislation and diving the GBR.
Mr J E Hodges, Director
Division of Workplace Health and Safety
Queensland Department of Employment etc.
0920-0935 Questions & discussion
0935-0955
Access and diving equipment for the GBR.
Mr Wayne Williams, Senior Manager
Mike Ball Watersports Inc., Townsville
0955-1015 Questions & discussion

Session 15 Diving safety on the GBR (II)

1045-1105
Medical preparation for diving the GBR.
Dr M Rooney, MB, BS
Diving Medical Practice, Townsville
1105-1120 Questions & discussion
1120-1140
Safe diving practices on the GBR.
Mr J Hardman, Operations Manager*
1140-1150 Questions & discussion
1150-1205
Night diving safety on the GBR.
Mr Colin Hodson
1205-1210 Questions & discussion
1210-1220
DIMS the diving accident monitoring study.
Dr Chris Acott, FANZCA, DipDHM

Session 16 Diving safety on the GBR (II)

1330-1350
The decompression illnesses
Dr Des Gorman, FACOM, PhD, DipDHM
Director of Diving and Hyperbaric Medicine
Royal New Zealand Navy, President of SPUMS
1350-1400 Questions & discussion
1400-1420
Rescue and retrieval on the GBR.
Dr J Gordon, FANZCA
Townsville General Hospital
1420-1430 Questions & discussion
1430-1450
Management of diving related illnesses in reef divers.
Dr Tom Fallowfield , MSc, MFOM, DipDHM
Director of Hyperbaric Medicine
Townsville General Hospital
1450-1530 Questions & discussion
1530
Close Meeting
Dr Des Gorman, President SPUMS

* Australian Institute of Marine Science, Townsville, Queensland.

For booking and travel arrangements contact

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

Telephone (03) 885 8818
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LETTERS TO THE EDITOR

UNITED KINGDOM INCOME TAX RELIEF

Inland Revenue, Personal Tax Division
550 Streetsbrook Road
Solihull B91 1QU
United Kingdom

8 October 1991

Dear Sir,

INCOME TAX RELIEF IN RESPECT OF ANNUAL MEMBERSHIP SUBSCRIPTIONS

A letter of approval is enclosed. The Society name will appear in the next edition of the list of approved bodies which is due for publication early in 1992. Inspectors of Taxes will not receive notification of the Society's approved status until then. Therefore if members wish to obtain a deduction for their subscriptions before the new list is published, they should explain when contacting their local Tax Inspector that the Society has only recently been approved and quote the Head Office reference shown above.

If there is any future change in the constitution or name of the Society, please let me know as soon as possible.

J.E. Miller (Miss)

Inland Revenue, Personal Tax Division
550 Streetsbrook Road
Solihull B91 1QU
United Kingdom

8 October 1991

Dear Sir,

INCOME TAX RELIEF IN RESPECT OF ANNUAL MEMBERSHIP SUBSCRIPTIONS

I am pleased to inform you that the South Pacific Underwater Medicine Society has been approved by the Board of Inland Revenue under Section 201 Income and Corporation Taxes Act 1988, with effect from 6 April 1990.

B. Jones

These two letters, published at the request of the Trearurer of SPUMS, will be of interest to members residing in the United Kingdom.

TECHNICAL DIVING

Fun Dive Centre
255-257 Stanmore Road NSW 2048

16.11.91

Sir

We are poised at the beginning of probably one of the most exciting eras in the history of diving. Not surprisingly, it is also a time of considerable confusion and misinformation.

Enabled by new technologies and techniques, from sophisticated computers to special mix gases, experienced divers are venturing beyond established limits, setting new boundaries, diving deeper, longer and performing dives that would have been thought unfeasible just a few short years before.

I have just returned from the USA where I had the unique opportunity of discussing "high tech diving" with some of the leading authorities in this field and to experience, first hand, the equipment and techniques used in this exciting development of diving.

"Technical Diving" had its humble beginnings in the mid 1980's. Prior to this, although many divers were regularly exceeding the 39 m sport diving limit to explore deep wrecks, walls and caves, the equipment and techniques used were primitive and dangerous as they pushed to the extreme limits and beyond.

Prior to 1985, only 4 heliox/trimix "special mix" dives had been carried out by sport divers. Regrettable, during one of these dives, a diver, due to ignorance, convulsed and died from breathing 100% oxygen at his 15 m decompression stop in accordance with the USN Heliox Decompression Tables.

Since 1985, some 400 heliox/trimix "special mix" dives have been conducted by sport divers without any major incidents. A brief overview of these dives is as follows:

Wookey Hole, UK, 1985 - trimix dive to 73 msw
Nacimiento Manti, Mexico, 1987 - trimix dive to 180 msw
South Andros Island, Bahamas, 1987 - over 60 dives on heliox to a maximum depth of 90 msw.
Wakulla Springs, Florida, USA, 1987 - 84 dives on heliox/trimix to a maximum depth of 93 msw.
Nacimiento Manti, Mexico, 1989 - trimix dive to 265 msw.
Florida, USA, 1991 - trimix dives to a maximum depth of 146 msw.

The use of "trimix" is well enough established in the U.S. that a major university, Florida State University, has approved it for use in archaeological work.

Although oxygen enriched air has been used by many divers overseas for the past 5 years or so to make dives to depths down to 39 msw safer, its use was banned by all the sport diving certification agencies.

This year a major break-through occurred with the sanctioning of oxygen enriched air diving by the National Association of Scuba Diving Schools (NASDS), the National Association of Cave Divers (NACD) and the Technical Committee of the National Association of Underwater Instructors (NAUI). Given the competitive nature of the sport diving industry, many believe that its only a matter of time before PADI and SSI follow suit and also accept oxygen enriched air diving.

Presently there are 100 oxygen enriched air instructors working through 30 oxygen enriched air dive stores in the USA. This is a 100% increase in both areas over the past 6 months. One dive store in Washington State has converted the majority of its customers to oxygen enriched air and is filling 300-400 oxygen enriched air tanks per month.

The demand for "Technical Diving" equipment has led to the development of a closed circuit sport diving set with 100% redundancy and an endurance of 8-9 hours at 90 msw, safer decompression tables using oxygen enriched air and 100% oxygen, nitrox and heliox dive computers, and a far greater understanding of many of the "grey" areas of diving medicine.

The "Technical Diving" trend is also emerging in Europe where a closed circuit sport diving set has been developed with 100% redundancy of all electronic modules and an operational depth of 450 msw.

"Technical Diving" has forced the re-examination of many existing traditional recreational diving practices and techniques. The use of compressed air and conventional sport diving regulators for dives greater than 57 msw is extremely dangerous and can lead to oxygen CNS toxicity convulsions.

Wes Stiles, one of the world's foremost cave divers with compressed air experience to depths greater than 90 msw, now refuses to dive deeper than 39 msw unless he used "special mixes". He learnt his lesson the hard way several years ago when he only just survived a CNS oxygen hit at 49 msw in a cave system.

"Technical Diving" offers the prepared, knowledgeable diver a chance to experience a realm not previously accessible to humans. There is every reason to think that, as our technology and knowledge advances, we will be able to push the envelope further.

Bob Cason

Readers are referred to the Editorial on page 1 for the less pleasant aspects of Technical Diving.

DECOMPRESSION SICKNESS ?

Telita Cruises
P.O.Box 303, Alotau
Papua New Guinea

Sir

A case of hysterical decompression sickness ?

At 0400 on the morning of October 19th 1991 I was awakened by one of our clients aboard our charter boat. He complained of numbness and tingling in his left arm, said he thought he might have decompression sickness and collapsed to the deck. He was distressed and shocked. Within three minutes we had him breathing 100% oxygen through a scuba regulator, wrapped up with a blanket in a comfortable chair and drinking water.

Within minutes he complained, by signals and writing on a pad, that he felt tingling in his right hand and that his knees were shaking. He had urinated just before waking me "a normal morning urination, yellow". During the next half hour he drank a litre of water.

His Oceanic dive computer was interrogated and the following dive profiles obtained:

Dive	Time	Maximum depth		Dive time
1	0715	24 m	80 ft	63 min multilevel
2	1030	11.8 m	39 ft	68 min
3	1325	6.6 m	22 ft	91 min
4	1540	6 m	20 ft	54 min
5	2030	10.3 m	34 ft	42 min

All dives were well within the No-stops limits of his computer.

After a few minutes on oxygen he felt better, decided that he could not feel anything after all in his right hand. His knees stopped shaking and he was no longer cold, clammy and sweating on his forehead. After 30 minutes on oxygen he felt no symptoms at all. After an air break of ten minutes we gave him another 15 minutes on oxygen as a precaution.

On questioning he admitted that the night before he had slept on his arm and it had "gone to sleep" and he thought that perhaps this had happened again. However he was very concerned about getting the bends and thought that he should do what he did and report it to me.

That afternoon he made a shallow dive with no problems, then continued the diving cruise for a further week making four or five dives a day with no problems.

Bob Halstead

SPUMS ANNUAL SCIENTIFIC MEETING 1991

THE PADI MEDICAL STATEMENT

Drew Richardson

Introduction

Scuba diving is an enjoyable and fascinating leisure activity. A 1988 study performed by Diagnostic Research Incorporated[1] indicated approximately 2.7 million active recreational scuba divers in North America. A broadening cross section of the general population is choosing scuba diving as a recreational activity.

The diving industry assumes an ethical and legal duty to inform student divers of the risk factors associated with diving. Interested in self regulation, the industry has banded together to promote diving safety and health while reducing the number of accidents and fatalities during the growth period of the past decade.

As an educational association, PADI has invested resources into the design of quality training programs and educational materials. This commitment is to ensure that divers are properly trained to dive safely and enjoyably after certification. Diver education plays an important role in accident prevention. A diver in training must demonstrate competence in the various cognitive and motor skill areas associated with learning how to scuba dive. In addition, they must develop proper judgement in order to take responsibility for themselves while diving after certification.

However, some accidents are related to the interaction of the aquatic environment and an individual's health. The 1988 Divers Alert Network (DAN) Report on Diving Accidents and Fatalities[2] indicates a portion of injured divers who were aware of their own medical problems made a personal choice to engage in diving. PADI believes that the incidence of diving accidents is likely to be reduced by utilizing a medically based screening process to exclude individuals, with certain medical problems known to be predisposing factors, from engaging in recreational scuba diving.

A standardized and objective assessment of medical risk was sought after by the diving educational associations who were members of the Recreational Scuba Training Council (RSTC). After several months of work, this was accomplished with the 1990 release of the RSTC Medical Statement. The member associations of the RSTC enthusiastically embraced such a milestone and applauded the physicians who worked on this project. Special recognition and thanks is deserved for Paul A. Thombs, MD, Medical Director, Hyperbaric Medical Center, and Brian M. Foley, MSc, Director of Technical Services, Hyperbaric Oxygen Therapy Systems, both of St. Luke's Hospital, Denver, Colorado for their major contributions to this milestone.

Each member agency has adopted the content of this statement into their medical forms. In the North American marketplace this represents eighty percent of the diver educational associations implementing this form into their respective training programs. The PADI Medical Statement is a reproduction of this form.

Medical screening for the recreational diver

The marketing effort of the Diving Instructional business attracts people of all ages. An important prerequisite to diver training is the medical screening of each candidate. As part of PADI's Standards, each candidate must read, complete and sign the PADI Medical Statement.[3]

It must be stated that a scuba instructor is not considered a medical expert. He should not be expected to make diagnosis or render definitive opinions as to whether a course applicant is medically eligible to participate in a scuba course. This responsibility should rest entirely with a qualified licensed physician. In North America and in other parts of the world, most diver training agencies do not require every student to undergo a medical examination by a licensed physician prior to enrollment in a scuba course. They do, however, require some type of medical screening.

The content and format of such screens differed widely until the introduction of the Recreational Scuba Training Council Medical Statement. The statement provided standardized guidelines with a pre-screening methodology on what constitutes medical eligibility to learn to dive. This reduced the problem of lay people being faced with medical decisions. Perhaps most importantly, the new medical evaluation and screening statement has medically based provisions to inform the non-diving physician of the contraindications to diving so that an informed recommendation may be rendered.

Development of the medical statement

When it comes to the issue of student medical eligibility for diving, the recreational diving community must defer to the hyperbaric medical community for expertise and guidance. The information in the PADI Medical Statement was developed by well known members of the Undersea Hyperbaric and Medical Society along with prominent physicians from DAN in conjunction with several professional instructor organizations affiliated with the RSTC. As a result of this multi-disciplinary approach, the statement represents consensus opinion of the experts. The new medical statement represents the culmination of a growing consensus within the North American diving medical community as to what constitutes medical eligibility to learn to dive. This is a very positive advance in the standardization of the diving medical screening process. Until its release, a comprehensive standardized format representing a medical consensus did not exist in the recreational diver training community.

It should be noted that the statement has evolved since its release with several improvements and revisions made through suggestions from the international medical community.

Design of the medical statement

The statement uses a student health screening questionnaire designed to be comprehensive enough to flag questions yet decrease the number of unneeded physical exams. Recognizing that no screening method can be perfect (there may be those who will knowingly circumvent safety efforts by giving false answers), the authors of the statement, in designing screening questions, made decisions as to whether the process catches unfit students adequately. The questions are quite thorough and conservative and probably direct some students to a physician for further screening when this issue has little impact on their safety.[4]

The statement is designed to accommodate the fact that the number and distribution of physicians with expertise in diving medicine makes it difficult for many diving students to get a reasonable risk assessment.

The statement has instructions to the physician in addition to an reference section so that physicians may be educated sufficiently about their patients conditions and diving physiology to make reasonable recommendations. DAN is willing to assist physicians further with difficult or unusual cases. Each area of screening identifies the relative and absolute contraindications for the examining physician to render an opinion.

The PADI Medical Statement is a vehicle to help the diving candidate, the examining physician and the scuba instructor ensure the student's medical fitness for diving. The statement specifically states that the student will be participating in diving activities and the physician is also given guidelines as to how specific medical conditions relate to diving.

Role of the diving candidate

At the beginning of every PADI course the first two pages of the six page statement are filled out by the student.[5] After explaining the purpose and importance of health and safe diving to the student, the medical history section requires the student to write a yes or no answer for every question. All blanks are checked by the instructor to ensure no questions are left unanswered. If a "yes" answer is given to any question, the student must be referred to a physician with the statement for examination and an unconditional medical approval prior to water activities. This releases the lay instructor from the historical burden of deciding whether a student should be seen by a physician or not.

In the past scuba instructors were occasionally placed in the uncomfortable position of wanting to teach a willing student to dive, but not knowing if diving could compromise the student's health.[6] With the new statement, a doctor makes a decision based on his knowledge and expertise in the medical field along with the patient history and the use of the guidelines written expressly for this purpose.

It is important to also state that the student may not assume medical responsibility for himself. It is important to identify these risks to the candidate and encourage honest in responding to the statement. This is done with the following statement:

"This is a statement in which you are informed of some potential risks involved in scuba diving and the conduct required of you during the scuba training program. Your signature on this statement is required for you to participate in the scuba training program offered by ....; Instructor..; located in the facility ....; in the city of .... and state of...

Read and discuss this statement prior to signing it. You must complete this Medical Statement, which includes the medical-history section, to enroll in the scuba-training program. If you are a minor, you must have this Statement signed by a parent.

Diving is an exciting and demanding activity. When performed correctly, applying correct techniques, it is very safe. When established safety procedures are not followed, however, there are dangers.

To scuba dive safely, you must not be extremely overweight or out of condition. Diving can be strenuous under certain conditions. Your respiratory and circulatory systems must be in good health. All body air spaces must be normal and healthy. A person with heart trouble, a current cold or congestion, epilepsy, asthma, a severe medical problem, or who is under the influence of alcohol or drugs should not dive. If taking medication, consult your doctor and the instructor before participation in this program. You will also need to learn from the instructor the important safety rules regarding breathing and equalization while scuba diving. Improper use of scuba equipment can result in serious injury. You must be thoroughly instructed in its use under direct supervision of a qualified instructor to use it safely.

If you have any additional questions regarding this Medical Statement or the Medical History, section, review with your instructor before signing."

A student having been declined medically may wish to assume his own risk and attempt to convince the instructor to enroll him in a scuba course. A publication on the legal aspects of diving instruction, published by PADI, called "The Law and The Diving Professional"[7] cautions instructors against this by stating: "It may be argued that the student, being aware of his conditions understands and assumes the risks accompanying his condition, but the student is no more a medical expert than the instructor. Further, the instructor may be negligent in not relying upon the physician's judgement, thus possibly creating an unreasonable risk of harm for the student". As a result, PADI Standards require the instructor to follow the instruction for use of the form and secure an unconditional approval from a licensed physician.[3]

Role of the physician

An important concern regarding medical approval to dive is that not all physicians are aware of certain physical and emotional factors peculiar to scuba diving.[8] In the past students requiring a physician's medical approval prior to diving have received approval from a physician who had no knowledge of diving medicine. In many cases this is of little significance, however, this becomes troublesome to the diving instructor and student when the candidate presents a medical history of asthma, diabetes, seizures, heart conditions or other conditions the diving medical community considers contraindications to diving, yet receives medical approval to engage in diving.[9]

In addressing this problem, the medical statement assumes (consistent with society's expectations) that a physician should be the decision maker. Physicians make daily decisions with their patients regarding risk to benefit ratios of diagnostic procedures and treatments. It is logical to extend this process to risk assessment in recreational scuba diving. The statement provides a medically based guideline to the physician that is diving specific. The statement assumes physicians have a sufficient background in physiology to learn enough about diving medicine to make informed decisions based on risk assessment. The attending physician is prepared for patient examination with the medical history by the following instructions:

"Recreational scuba (self contained underwater breathing apparatus) diving has an excellent safety record. To maintain this status it is important to screen student divers for physical deficiencies that could place them in peril in the underwater environment.

The Recreational Scuba Diver's Physical Examination contains elements of medical history, review of systems and physical examination. It is designed to detect conditions that put a diver at increased risk for decompression sickness, pulmonary over-inflation syndrome with subsequent cerebral gas embolization and loss of consciousness that could lead to drowning.

Additionally, the diver must be able to withstand some degree of cold stress, cope with the optical effects of water and have a reserve of physical and mental abilities to deal with possible emergencies.

The history, review of systems and physical examination should include, as a minimum, the points listed below. The list of contraindications, relative and absolute, is not all inclusive. It contains the most commonly encountered medical problems that put the diver at risk, and (lead him) to consider the individual patient's state of health.

Diagnostic studies and specialty consultations should be obtained as indicated to satisfy the physician as to the diver's status. A list of references is included to aid in clarifying issues that arise. Physicians at the Divers Alert Network (DAN) are available for consultation by phone (919) 684-2948 during normal business hours. For emergency calls, 24 hours, 7 days a week, call (919) 684-8111.

Some conditions are absolute contraindications to scuba diving. Conditions that are absolute contraindications place the diver at increased risk for injury or death. Others are relative contraindications to scuba that may be resolved with time and proper medical intervention. Ultimately the physician should decide with the individual, based on his knowledge of the patient's medical status, whether the individual is physically qualified to participate in scuba diving.

Remember at all times that scuba is a recreational sport, and it should be fun, not a source of morbidity or mortality."

Physicans are then guided through each screening area which identifies relative and absolute contraindications in the following areas, cardiovascular system, pulmonary, neurological, otolaryngological, gastro intestinal, metabolic, endocrinological, pregnancy, hematological, orthopedic and behavioral health.

A bibliography and endorser contact information is also provided for attending physician reference.

Role of the diving instructor

The success of the screening process depends on instructors providing the screening forms to potential students and encouraging them to be honest when completing the questionnaire as a matter of health and safety. Instructors can discourage students with medical problems form diving if they feel that their chances of receiving physician approval is low. If the answer to a screening question is unclear, the instructor can tell potential students that their case is complex and invite them to discuss medical issues with their physician prior to completing the questionnaire.

When a physician gives approval to a student as to his medical eligibility to dive, the instructor must then make a choice as to whether or not he wishes to take the student under instruction. If an applicant is medically approved for diving and the instructor believes the student has a condition that may not be suitable for diving it is appropriate for the instructor to inquire from the student and seek further guidance for the physician who examined the student. The Law and The Diving Professional[7] discusses this point "ultimately, the scuba instructor must make the final decision as to whom will be permitted to take a scuba course. Scuba instruction is not a right to which all persons are entitled. It is a private recreational choice on the part of both the instructor and the applicant. An instructor has absolutely no legal obligation to accept every applicant. Therefore, keeping in mind these considerations in the area of medical fitness, an instructor may exercise discretion by refusing admission to an application if, the the instructors judgement, there is cause for concern".

As stated earlier, it is important for an instructor not to assume responsibility for medical judgements or approvals. This is solely the physician's area of expertise, the instructor is required by PADI, to leave this responsibility to the physician.

Conclusions

By using the PADI Medical Statement, instructors, students and physicians are all assured they are doing their best to ensure individual health for diving. The process of student, instructor and physician interaction is designed to provide information about student medical history and risk identification to make an informed recommendation prior to scuba diving. This in turn will support a continuance of safe and enjoyable scuba diving for the majority of the interested population.

References

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SPUMS policy is that every intending diver should have a medical from a doctor trained to do diving medicals before starting to dive.

With this issue of the Journal comes a copy of the SPUMS submission to Standards Australia Committee CS/83 detailing what is considered necessary for a diving medical for recreational divers.

Further copies are available from the Secretary of SPUMS, C/o Australian College of Occupational Medicine, P.O.Box 2090, St Kilda West, Victoria 3182, Australia.

THE RECREATIONAL DIVE PLANNER AND THE PADI EXPERIENCE

Raymond E. Rogers

Introduction

In 1988, the Professional Association of Dive Instructors (PADI) began distributing the Recreational Dive Planner (RDP) as an alternative to the US Navy tables, which had long been accepted around the world as a de facto standard for recreational use. Although the USN tables were neither designed nor tested for the way they were commonly used[1], their very familiarity made them tolerable to most experts in the field of diving safety. The most likely reason that they were well accepted by the medical and scientific communities was not from any inherent excellence, but from the fact that divers who used them had a very low rate of decompression sickness (DCS).[2,3]

As dependable as the USN tables were, they were far from perfect and were criticized in many quarters. Some considered them unnecessarily conservative and restrictive for repetitive diving.[4] The RDP is a result of this body of opinion, and so are virtually all dive computers in the world. But there was another opinion which was shared by some well-respected individuals, an opinion which holds that the old tables were too generous.[5,6] After all, hundreds of DCS cases were being treated each year,[7] and, at least until recently, the overwhelming majority of divers who experienced DCS had used USN tables.[8] Because of this, some people were understandably concerned that any procedure which allowed more bottom time was something to be feared.[9,10]

Testing of the RDP has been reported to SPUMS on a previous occasion.[11] The reports were well received, but some observers were pragmatic enough to realize that a favorable laboratory outcome does not guarantee acceptability in practice. They wanted to know what the experience would be after many divers were using the RDP. This paper discusses that experience. As with all diving statistics, answers are hard to come by, and when given, are usually suspect, but the duty to search for them still exists. A superficial examination of reports about diving and dive accidents reveals the inadequacy of most of these reports, and a careful examination reveals that they are not as good as they seem. Yet, it is possible to work only with the materials at hand. These caveats having been pronounced, it may be said that the experience with the RDP has been good.

DAN accident reports

The best source of information is the Divers Alert Network (DAN), even though a chronic shortage of funds limits DAN in its ability to be as thorough as it would like.[12] DAN has improved its data collection and analysis remarkably in the last few years, but it is the first to admit that it has a way to go. DAN deserves credit for the progress that it has made and it will continue to improve. The DAN 1989 Report on Diving Accidents and Fatalities has just been released, and is the most current, finalized information available.[13] This means that there is no official information about the last 18 months, a period when several new dive computers were introduced, and when PADI phased out the old USN tables in favor of the RDP. There is, however, some preliminary and unofficial information.

Even when reports exist, it does not mean that desired answers are available. It is necessary to discriminate between what is written and what may have really happened. Examination of accident reports demonstrates how many cases are caused by diver error. Only a small number occur with divers who did things correctly and still had DCS, or as it has been called "an undeserved hit."

A detailed study of the first 33 RDP incidents reported to DAN in 1989 revealed the nature of this problem, and the analysis was published in mid 1990.[14] The rest of the 1989 reports were similarly studied when they became available. The results of this analysis were combined with that of the first, and are summarized here. Some of the incidents were more apparent than real. Several of the cases clearly were from use of the old USN tables, but they were marked as "RDP" and thus were listed on the database printout. A few divers were using computers with the RDP as a backup, and both methods were recorded. Of those that did appear related to the RDP, five categories seemed to characterize the incidents; and some reports fit in more than one of these categories. A few examples are listed to illustrate each category. In all examples the depth/time is given followed by the surface interval, usually in minutes, in brackets.

Rule violations

21 cases of DCS were obvious rule violations. Two examples are:

Profile: 105/24
Over limit of 110/16 by 8 minutes; no emergency stop.

Profile: 90/22 (90) 90/32 (90) 80/35.
No safety stops were ever made; 2nd dive was over limit; did not quit for 6 hours as required; rapid ascent (low on air); over limit again on 3rd dive; rapid ascent (low on air again); felt numbness/tingling before the last dive but continued to dive; drug use.

Dubious reporting

20 cases of DCS were dives which are suspicious because of dubious reporting. Four examples are:

Profile: 90/20 (3.5 hour) 50/25 (1 hour) 30/40
Profile: 80/20 (80) 80/20
Profile: 40/40 (20) 40/40
Profile: 30/35 (90) 35/40 (90) 35/60 (90) 40/25 (60) 40/20 (75) 65/30. A marginal note said "Don't remember exactly".

Equipment malfunction

Five cases reported equipment malfunctions such as stuck inflator hoses, computer shorted out and the diver changed to RDP in mid-dive. Some of these reports were obviously incomplete such as timing device failures, with no report of how the dive time was determined!

Benign exposures

21 Cases of DCS occurred with benign exposures

TABLE 1

REPORTED SURFACE INTERVALS SHOWING TENDENCY TO ROUND-OFF

"EXACT"			ROUNDED		
Obviously	Possibly	Probably	Obviously	Possibly	Probably
22	20	35	1:30	30	90
33	40	65	2:00	30	90
34	50	95	2:00	45	90
48	50	95	3:00	45	90
48	140			45	90
52	140		1 hour	45	90
92	140		3.5 hours	45	105
102	140			60	120
142	150		2 .5 hours	60	165
152	160		3 hours	60	165
	200			60	180
	220		30 - 45	75	180
					210
					210
					300

permitted by any system. Four examples are:

Profile: 40/43 (52) 30/46
Profile: 92/10
Profile: 70/30
Profile: 35/20

Permitted by RDP but not by USN tables

Three cases of DCS occurred with exposures permitted by the RDP but not by USN tables.

Profile: 50/33 (50) 50/33 (50) 60/29
Profile: 51/37 (60) 30/40 (45) 50/47
Profile: 50/47 (150) 60/49 (140) 50/51

Diver error is not specific to the RDP. It applies across the board to all divers and to all decompression procedures. Because it is global in nature does not mean that it less important. The opposite is true. Individuals with physiological aberrations may be beyond the reach of those concerned with safety, but correction of diving deficiencies is an area that is amenable to improvement.

As a further observation on "Dubious reporting", Table 1 shows surface intervals in two groups: those that seem exact, and those that seem rounded off to the nearest quarter-hour. It is apparent that many divers reconstruct profiles *ex post facto*. Note that even those that appear exact usually end in "0" or "5".

Table 1 is a discouraging list for anyone who desires a valid appraisal of the RDP. Fortunately, a few facts are available to help evaluate the RDP. Through 1989, we know the total number of DCS cases reported to DAN, the number of these cases associated with the RDP,[13] and the number of RDPs distributed (Table 2).

TABLE 2

FOUR YEAR SUMMARY OF DAN AND RDP DATA

YEAR	DAN cases	RDP cases	Number of RDPs
1986	562	-	-
1987	602	-	-
1988	553	11	188,958
1989	678	59	417,972

The number of RDP cases for 1988 may be deceptively low. The RDP was available only part of that year and took time to become widely used. Information for 1990 is incomplete, but unofficially, the incidence rate seems to be about the same as in 1989.

It is possible to reach a number of conclusions from this information.

For the only full year (1989), 9% of the DCS reports were related to the RDP, and 91% of the DCS reports were unrelated to the RDP. The number of DCS reports increased from 553 in 1988 to 678 in 1989, or by 125. 53% of the reports in this increase were unrelated to the RDP.

If the RDP did not exist, RDP divers would have used another procedure. On the improbable assumption that none of the RDP divers would have DCS, the DAN totals of Table 2 would be as in Table 3, or a 4-year average of 580.

TABLE 3

FOUR YEAR SUMMARY OF DAN DATA (IF ALL RDP DATA IS DELETED)

YEAR	DAN cases
1986	562
1987	602
1988	542
1989	619

Making the more likely assumption that, if the RDP divers had used another procedure, some of them would have had DCS anyway, the totals would be consistent with the historical annual increases in the number of DCS cases.

Estimates of percentage of RDP users

Anyone investigating diver safety faces the necessity of working with "soft" data, and a difficulty with evaluation of dive accidents is that it involves multiplying one estimated number by another estimated number. One is an estimate of the dives performed by an "active diver" and the other is an estimate of the active divers. Both these numbers are controversial, especially the number of active divers.[15] Additional disagreement relates to the "drop-out" rate,[16] since this determines the number of active divers. The SPUMS Journal ran a series of articles on the topic several years ago. The issue was not resolved and may never be, and this is not an attempt to reopen the controversy. It is merely a suggestion to establish a plausible basis of comparison that can provide a reasonable perspective.

Estimates of the number of active divers have ranged from 700,000[15] to 2,700,000,[17] with an active diver being defined as one making at least three dives per year.[18] This yields, at a minimum, a range of 2,100,000 to 8,100,000 dives per year. The reality is that anyone who dives at all probably dives more than three times a year, making the latter number much larger.[2] The implication is that one figure may differ from another by a factor of four (or more) and still be within bounds of published estimates. There is no way of learning the number of dives performed around the world, and it is therefore more rewarding to discuss percentages. If estimates are within an order of magnitude of being correct, that may be as much as can be expected. The following approximations are presented with the stipulation that they should not be interpreted too rigidly.

A survey has shown that divers drop out at a rate of 15% within the first year after certification, 8% in the second year, 10% in the third year and 20% in the fourth year. Within two years following certification, 77% remain active.[19]

Almost 585,000 entry-level divers have been certified with the RDP. If the erosion rate is as described, a cumulative 496,000 of these divers would still be active. (Since the RDP is relatively new, these figures are fairly reliable; there is less anecdotal evidence associated with them than with statistics that go back 35 years.) Other active divers have acquired about 160,000 RDPs outside a certification program, and presumably, most of these are used today. Previously certified divers who begin to use the RDP reduce the number of non-RDP users and simultaneously increase the number of RDP users. Applying the above erosion data to this group yields a number of 131,000 RDPs in active use.

Combining new and previous divers, (arbitrarily decreased by 20%), leaves an estimated total of (496,000+131,000)x0.8=502,000 divers who are presumed to use the RDP actively.

If the number of active divers is the largest estimated,[17] then RDP users are (502,000/2,700,000)x100=18% of the total. If the number of active divers is the lowest estimated,[17] then RDP users are (502,000/700,000)x 100 = 72% of the total. A superficial inspection of divers at most dive sites will suggest that the first figure is too low, and the second is self-evidently too high.

If a number is chosen halfway between the extremes, there would be 1,700,000 active divers. RDP users would represent (502,000 / 1,700,000) x 100 = 30% of active divers, a figure that is perhaps debatable but not unrealistic. Even if this calculated percentage is too large by half, RDP users would nevertheless represent 20% of active divers, and if too large by as much as a factor of two, RDP users would represent 15% of active divers. DAN accident information relates approximately 9% of DCS reports to the RDP.[13]

Conclusion

No evaluation or analysis can be any better than the data on which it is based. Most dive accident reports are flawed. They are almost entirely subjective, usually being based on information provided by the affected diver, who is possibly too ashamed and embarrassed to reveal the truth. The problem is made worse in that record-keeping is often so poor that a diver may not know the truth at all, and has to resort to haphazard guesses. Nevetheless, much time is spent analyzing this defective information, but until better methods of data collection are developed, data interpretation will remain weak. If this problem could be significantly reduced, causes of accidents could be better identified, and diving safety would be enhanced.

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TRIAL OF IN-WATER OXYGEN RECOMPRESSION THERAPY IN ANTARCTICA

Peter Sullivan and Attila Vrana

Abstract

In recent years the Australian National Antarctic Research Expeditions have carried out several extensive diving programs in Antarctica. As access to a recompression chamber in this situation is usually impossible, a case of decompression sickness would present a major therapeutic problem. It has been suggested that, despite the extremely cold conditions, the technique of emergency recompression in water, using oxygen, may be applicable even in Antarctic waters. This paper presents the results of thermal monitoring carried out during two simulations of the technique under actual Antarctic conditions. The first trial had to be aborted after 90 minutes when one subject sustained a significant drop in his core temperature. In the second trial a heavier subject was able to maintain an acceptable rectal temperature for the entire 2 hours 36 minutes duration. From this it is concluded that, using current diving equipment, the technique cannot be adequately relied upon for the treatment of decompression sickness. For the technique to be safely used, even better thermal insulation than that currently in use would have to be employed.

Introduction

The concept of using oxygen underwater for the emergency treatment of decompression sickness in remote areas was first suggested by Edmonds in the early 1970's, although not published until 1976.[1] It was devised as the result of a number of cases of decompression sickness occurring in extremely isolated areas of the south-western Pacific, where evacuation to a recompression chamber would have involved a delay of many hours or even days. Originally, it was hoped that this technique would prove adequate for the treatment of minor cases, and prevent deterioration in serious cases until suitable transport could be arranged. Not only was it successful in these aims but, in a number of cases of neurological decompression sickness, the procedure resulted in dramatic improvement and even cure. Indeed, the technique has proven so effective that it has been approved, although only for emergency use in areas remote from a chamber, by the Royal Australian Navy[2] and in the 1979 Australian Diving Standards (AS 2299).[3] In recent years, the United States Navy approved a modified version of oxygen in-water recompression therapy, but only as an option of last resort.[4] At the Twentieth Undersea Medical Society Workshop on the Treatment of Decompression Sickness members concluded that while they could not recommend the widespread use of underwater oxygen treatment, they did note: "In remote conditions, with expert and experienced personnel, and when procedures have been fully planned and the proper equipment is at hand, workshop members recognize that the technique has value".[5]

Over the last decade the Australian National Antarctic Research Expeditions (ANARE) have carried out several extensive diving programs, particularly at Davis Station, Antarctica. This surely must be one of the most isolated dive locations in the world, located as it is some 220 km below the Antarctic Circle, cut off from shipping by sea-ice for nine months of the year, and lacking facilities for air transport. In the absence of a recompression chamber the dive team was acutely aware of the need for safe diving procedures. The dive tables (1972 RNPL/BS-AC) were modified accordingly by adding extra increments to both depth and time, and no dives requiring decompression were permitted. Even so, the possibility of decompression sickness could not be entirely excluded and the options for treating such a case had to be considered. One such option was the use of in-water oxygen recompression therapy.

Since this therapy takes between two and three hours (depending on the severity of the case and the rate of improvement), cold water is usually considered a contra-indication to the use of underwater oxygen therapy.[6] Even in the tropical waters of Central Queensland, one such treatment had to be abandoned when the patient reported that he was becoming too cold and insisted on terminating the dive.

In the summer of 1981/82 Carl Edmonds carried out a trial of the oxygen underwater equipment at Davis Station. One diver acted as the stationary "patient" and wore a dry suit, albeit an ill-fitting one, while the other wore a 9 mm wet suit and was free to swim about.

Neither diver was monitored and thermal stress was assessed purely on subjective grounds. The trial was terminated after 1 hour 15 minutes when the "patient" started to shiver and complained of feeling cold. Despite this result, Edmonds concluded that the underwater oxygen system could be employed in the Antarctic, provided that better thermal protection was used, such as a thin neoprene wet suit under a dry suit.[7]

The 1985 diving program was carried out on a considerably more sophisticated level: all members of the six-man dive team wore custom made dry suits and band masks; breathing gas was supplied from an air-bank kept in the warmed rear-section of one of the vehicles; and dives were carried out from a heated dive shelter (Figure 1).

In addition, real-time monitoring of both rectal and skin temperatures was able to be conducted. It was felt that, using this equipment, it might be possible toconduct a trial of a full underwater oxygen recompression therapy safely . Certainly we wished to carry out a monitored trial of the procedure rather than being forced to attempt it for the first time with a genuine case of decompression sickness.

Materials and methods

The technique of underwater oxygen therapy is as follows: the patient is lowered along a shot line to 9 m, breathing 100% oxygen from a surface supply. For comfort he should be slightly overweighted and resting in a harness or sling. Ascent is commenced after 30 minutes in mild cases, or 60 minutes in severe cases, if significant improvement has occurred. These times may be extended for another 30 minutes if no improvement has occurred. The ascent is made in steps of 1 m every 12 minutes. The patient should always wear a full face mask and must be accompanied by another diver at all times.

For the purposes of this trial the intermediate therapeutic profile was chosen,1 hour at 9 m and an ascent taking a further 1 hour 36 minutes. Although the risk of cerebral oxygen toxicity is minimal at this depth, for reasons of both safety and ease of implementation the trial was conducted using air rather than oxygen. It is considered that the difference in the thermal conductivity of the two gases would have no significant effect on the respiratory heat loss. However, the dive panel did have provision for a separate oxygen supply to the "patient", if required.

The anthropometric characteristics of the two divers who carried out the trials are listed in Table 1. The estimate of Mean Weighted Skinfold Thickness (MWST) was based on the work of Edwards,[8-9] such that:

$$MWST = 0.2_{\text{Biceps}} + 0.2_{\text{Triceps}} + 0.35_{\text{Subscapular}} + 0.25_{\text{Suprailiac}}.$$

Body surface area was estimated according to DuBois and DuBois[10] and percentage body fat was as calculated by Durnin and Womersley.[11]

Subject 1 had carried out 54 Antarctic dives within the previous year and Subject 2 had performed 24. Even if acclimatization to cold in Antarctic divers does occur (and there is some evidence to suggest that it does not [12]), it would appear unlikely to have contributed to any significant difference between the two divers.

Both divers wore the following: polypropylene underwear (which carried the thermistor leads in specially sewn-in channels), 3 mm (1/8") Thinsulite™ undergarments and boots, dry suits (CF200X, Diving Unlimited International Inc., San Diego, California), band masks (Kirby-Morgan), and three-fingered 6 mm (1/4") neoprene mitts. In each mitt were two 10 g magnesium-iron heat-bags. When working properly these bags generate heat by the exothermic reaction of the two metals in salt water.[13] However, in our experience their performance was quite variable. The band masks not only fulfilled the requirement for a full-face mask but also allowed for verbal communications throughout both trials.

The trial dives were carried out approximately 1 km

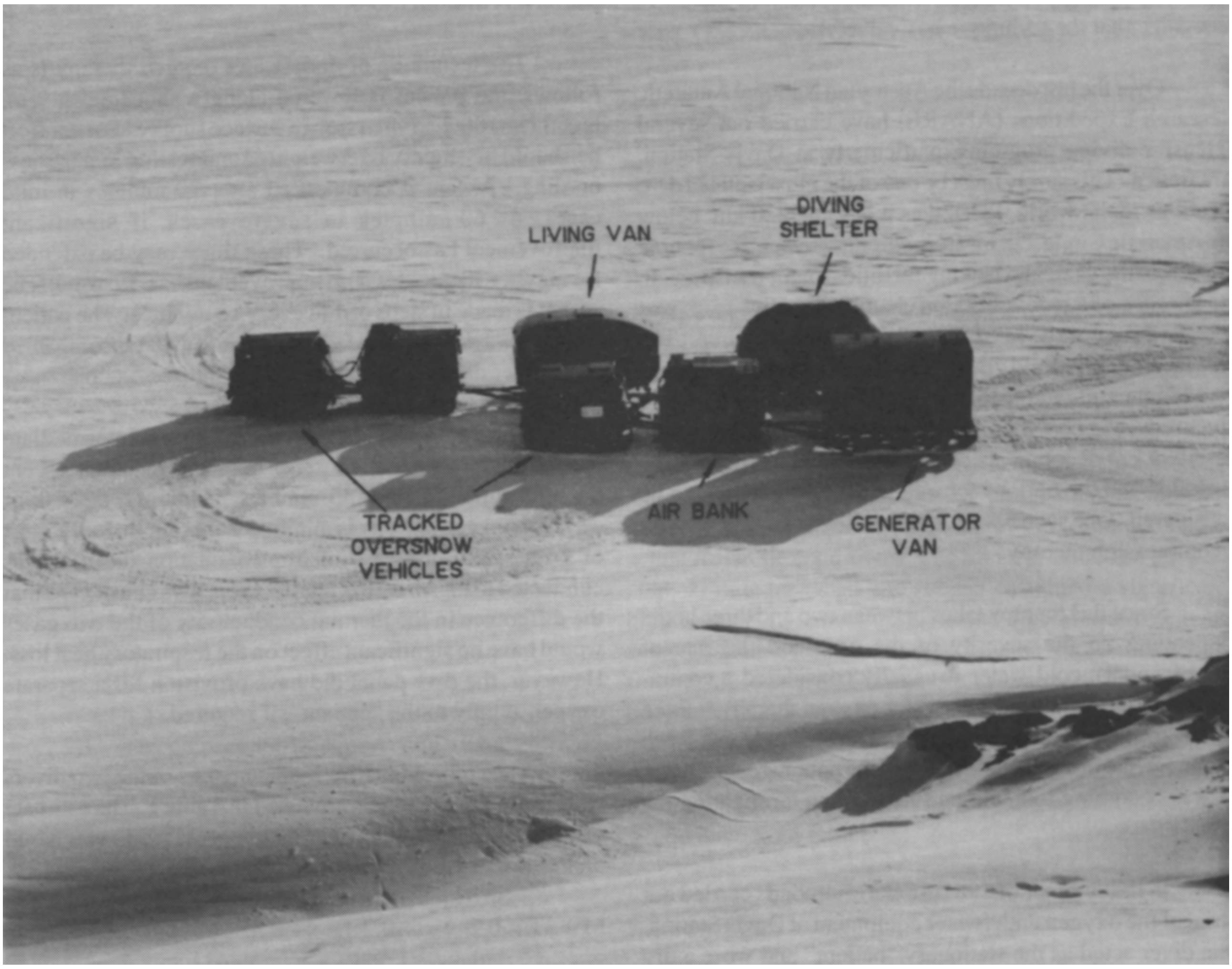

Figure 1. Diving convoy on the sea-ice in Antarctica.

TABLE 1

ANTHROPOMETRIC CHARACTERISTICS OF EXPERIMENTAL SUBJECTS

Subject	Age (years)	Height (cm)	Weight (kg)	MWST (mm)	Surface area (m^2)	Body fat (%)
1	30	178	70.1	7.4	1.87	15.6
2	42	189	92.5	9.0	2.20	21.0

from Davis Station in some 10 m of seawater. The sea-ice was 170 cm thick, enabling the warmed dive shelter to be parked directly over the dive-hole. The temperature of the seawater at the time of both trials was -1.4 °C.

Both subjects were instrumented with eight skin thermistors (YSI 409B, Yellow Springs Instrument Co., Yellow Springs, OH.) and a rectal probe (YSI 401) inserted 10 cm. Information from each of these thermistors (plus ECG and voice communication) was transferred via a 20-wire cable in the umbilical to the dive shelter. There the results were recorded every minute on a datalogger and transferred to a microcomputer. Scaled data were displayed on a video screen and printed out after each scan. The selection of thermistor sites was as per Adolfson, Sperling and Gustavsson.[14] (Figure 2).

Mean skin temperature (Tsk) was calculated as

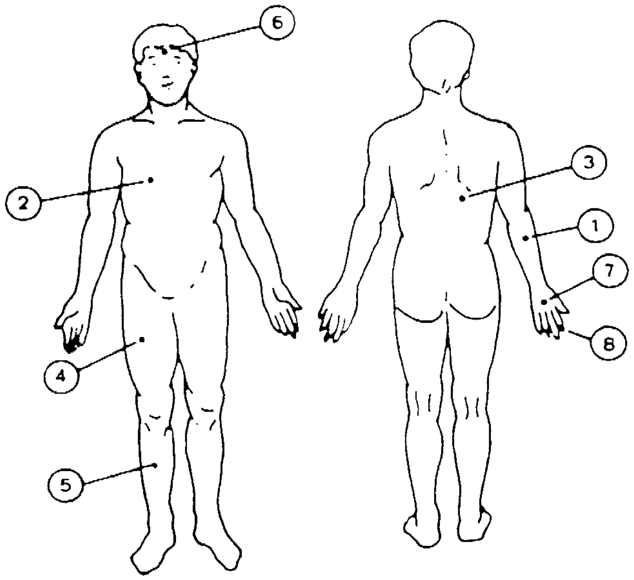

Figure 2. Thermistor locations

follows:

Tsk = 0.07 T_6 + 0.175 (T_2 +T_3 + 0.05 T_7 + 0.14 T_1 + 0.19 T_4 + 0.2 T_5. Mean hand temperature was calculated as the mean of T_7 and T_8.

For the trial to be considered successful it was intended that the "patient" should not only remain moderately comfortable throughout the full 2 hour 36 minutes of the treatment table, but that his thermal parameters should be within the limits established by the CIRIA/ UEG group.[15]

a Deep body core temperature should not fall below 35.5 °C.

b Mean skin and local head temperature should not fall below 25 °C with no local measurement below 20 °C except for hands and feet which should be maintained above 15 °C (for useful work in the fingers) and above 10 °C to prevent pain and possible cold injury over long dives.

Results

TRIAL ONE

In the first trial the smaller diver, Subject 1, acted as the stationary "patient" and Subject 2 was his attendant, maintaining the same depth but free to swim about. Both subjects started with a slightly elevated rectal temperature as a result of wearing their dry suits for some time inside the warmed dive shelter. Subject 1's rectal temperature fell steadily from the startt of the dive. After 90 minutes it seemed highly unlikely that he would be able to maintain a rectal temperature above 35.5 °C for the required 2 hours 36 minutes, so the trial was aborted. On leaving the water his rectal temperature suddenly dropped over a 2 min period

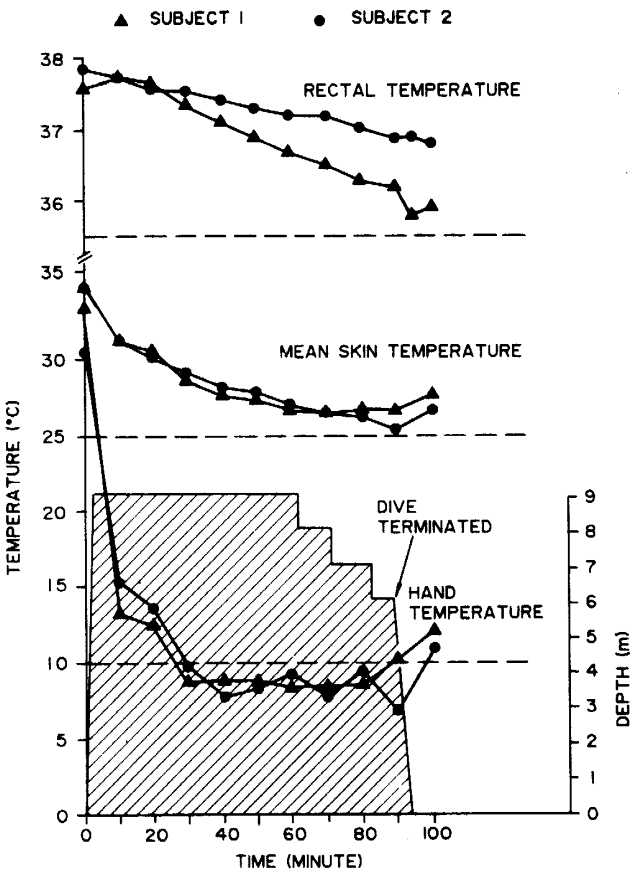

Figure 3. Trial 1 of oxygen in-water recompression therapy. The shaded area indicates the dive profile. The dotted lines indicate the UEG minimum acceptable temperatures. Subject 1 was the stationary "patient". The trial was aborted because of the fall in his rectal temperature.

from 36.2 °C to 35.8 °C, the familiar "after-drop" effect.

Subject 2 reported much less thermal discomfort and his rectal temperature demonstrated a much slower fall (Figure 3). Even after 90 minutes his core temperature had only fallen by 0.5 °C.

In spite of the difference in rectal temperature, both subjects maintained a very similar mean skin temperature, just above the minimum acceptable level. However, there was one noteworthy difference; after the first few minutes Subject 1 had a shin thermistor reading about 6 °C lower than Subject 2. This resulted from the stationary "patient," Subject 1, maintaining a vertical position with subsequent leg squeeze, while his attendant, Subject 2, swam about horizontally.

Despite the exothermic heat-bags the mean hand temperature of both subjects fell below the recommended minimum (10 °C) within 30 minutes of commencing the

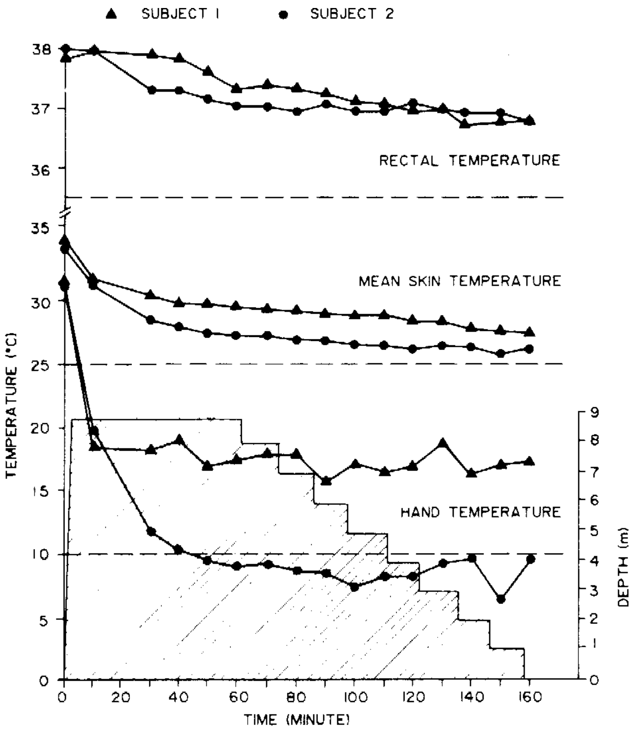

Figure 4. Trial 2 of oxygen in-water recompression therapy. The shaded area indicates the dive profile. The dotted lines indicate the UEG minimum acceptable temperatures. This time subject 2 was the stationary "patient" and maintained an acceptable rectal temperature. Data for the twenty minute mark is missing because of a temporary malfunction in the monitoring equipment.

dive.

TRIAL TWO

In the second trial it was the heavier diver, Subject 2, who took the role of the stationary "patient". As shown in Figure 4, he sustained a drop in rectal temperature of 0.8 °C during the first 30 minutes. From then on he was able to stabilise his core temperature at around 37.0 °C for the remaining 2 hours of the trial. Though not actually distressed by the cold he reported that it could not be considered as a particularly comfortable dive.

The attendant, Subject 1, was free to swim about and did so whenever he felt himself becoming cold. As a result he also was able to maintain an acceptable rectal temperature and fared much better than he had done on the first trial.

Again, both subjects were able to maintain a mean skin temperature above the recommended limit. However, unlike the first trial, where both subjects had very similar mean skin temperatures, this time Subject 1 consistently had a skin temperature 2-3 °C above that of Subject 2. This was partly a result of his considerably warmer hand temperature, and partly because, once again, the horizontal attendant had a significantly higher (8 °C) shin reading than did the vertical "patient".

Subject 2's decline in hand temperature followed much the same pattern as it did in Trial 1, and after approximately 40 minutes fell below 10 °C. However, neither on this dive, nor on any of the 150 other dives which were carried out during the year was there any evidence of non-freezing cold injury to the hands. Interestingly, Subject 1's right hand remained comparatively warm, about 17 °C, apparently because on this occasion the exothermic heat-bags worked adequately.

Discussion

It is not surprising to find that it was the heavier "patient" who was able to maintain an acceptable rectal temperature for 2.5 hours, while the thinner diver sustained a significant drop in his core temperature when in the "patient" role. This only confirms the importance of the insulating role of subcutaneous fat previously demonstrated by Keatinge, Webb and others.[16-17]

Also, the results of these two trials confirm the view expressed by Hayes[8] that a diver working in sub-zero water will need insulation of about 2 togs (1.3 Clo) to maintain comfort, (a solid neoprene dry suit with Thinsulite undergarments has an insulation value of 1.9 togs in water), but that once he stops working the requirement rapidly exceeds 4-5 togs.

One final point to consider is that in both trials the subjects were normothermic at the start of the "treatment". However, in a real-life situation it is quite possible that the dive which "bent" the diver might also have rendered him somewhat hypothermic.

Remembering that symptoms of decompression sickness often present within one hour of surfacing it is likely that the victim may not be adequately rewarmed at a time when the diving physician is considering subjecting him to a further 2 to 3 hours of immersion in sub-zero water. Ascertaining the patient's core temperature would be essential before even contemplating the use of in-water oxygen therapy in such conditions.

While it would be unwise to extrapolate too far on the basis of only two trials, these simulations of the underwater oxygen recompression technique demonstrate that, even using some of the best passive thermal protection equipment currently on the market, there still remain major problems concerning the risk of hypothermia and local cold injury. Although one large diver was able to undergo a full 2.5 hour "treatment", a smaller, indeed average sized, diver demonstrated a significant drop in core temperature after only 90 minutes and the "treatment" had to be abandoned. Therefore, the technique cannot be considered sufficiently reliable in such cold waters and a proper recompression facility should be provided for all future large-scale Antarctic diving programs.

Despite the above comments, in an extreme emergency, where access to a chamber is impossible, underwater oxygen recompression might still be worth attempting, especially if diver monitoring is available to increase the safety of the procedure. For even though a full 2 or 3 hour therapeutic profile may not be possible, it appears that at least an hour of oxygen at 2 ATA could normally be safely delivered and might well prove to be of considerable value.

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Keywords

Cold, diver monitoring, decompression sickness, recompression, hyperbaric oxygenation, skin temperature.

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CLINICAL REVIEW ROYAL ADELAIDE HOSPITAL HYPERBARIC MEDICINE UNIT 1990

Chris Acott

Introduction

Since its inception in 1986 the Royal Adelaide Hospital (RAH) Hyperbaric Medicine Unit has had a steady clinical work load (Table 1).

During 1990 the medical staff of the Unit was a full-time Director, four Specialists, a part-time General Practi-

TABLE 1

Year	No of Patients	Patient Treatments	Chamber Runs
1986	109	565	319
1987	169	1480	759
1988	122	1379	654
1989	117	1033	548
1990	116	792	477

tioner and one Visiting Specialist involved in research. The Director and specialists all had other clinical commitments in the RAH Anaesthesia and Intensive Care Department.

The nursing staff consisted of a Charge Sister, one full-time RN and two part-time RNs. As well there was a nursing pool of 26, 4 of whom had Critical Care nursing skills. There were 2 full time Hyperbaric Technicians.

Patient treatments

The patient numbers treated were similar to previous years (Table 1).

The complication rate was low. There were 3 deaths, one each from cyanide poisoning, carbon monoxide poisoning and cerebral arterial gas embolism. Two patients required myringotomies because they could not equalize. One patient developed a pneumothorax.

Cases treated

Carbon monoxide poisoning, decompression sickness, osteoradionecrosis and chronic refractory osteomyelitis were the main conditions treated. The full list appears in Table 2.

Carbon monoxide poisoning

Sixty one patients were treated. Thirty one were from accidental exposure and 30 from suicide attempts.

The total number of treatments was 205. The average number per patient was 3.4 with the range being 2 to 8.

The range of carboxyhaemoglobin levels on admission was between 6-77 mg% averaging 24 mg%. The level on admission had no correlation with the number of treatments the patient received. Table 3 lists the causes of the accidental exposures. Faulty gas heaters and faulty car exhaust predominate. Forklift drivers still continue to be exposed.

TABLE 2

CASE LOAD

Carbon monoxide	61
Decompression sickness	20
Osteoradionecrosis	9
Gas gangrene	5
Osteomyelitis	4
Wound healing	3
Idiopathic hearing loss	2
Spinal sydrome (ischaemic muscle)	2
Cerebral arterial gas embolism (CAGE)	1
Venous stasis ulcer	1
Necrotising fascitis	1
Cyanide poisoning	1
Chemical inhalation	1
Non-healing bone graft	1
Cerebral ischaemia	1
Post-partum fitting	1

TABLE 3

CARBON MONOXIDE POISONING ACCIDENTAL EXPOSURE

Fire fighters	(2Country Fire Service)	3
Faulty car exhaust	(2 families of 4)	8
Faulty gas heater		8
House fire		2
Accident at work		3
Fork lift drivers		4
Fire in prison		2
Miners		1

Experience at the RAH contradicts the opinion of the Australian National Institute of Occupational Health and Safety which stated in 1989 “fire-fighters who are working on bushfires...are unlikely to experience hazardous exposure to carbon monoxide”.[1]

A hose attached to the car exhaust is still a popular way to try to commit suicide. In majority of cases the hose fell off, while some changed their minds, and in others the car ran out of petrol. Only 1 patient, who attempted suicide, had had a previous exposure to carbon monoxide. This was from a faulty car exhaust.

At 18 month follow-up 2 patients had neurological sequelae (short term memory loss and poor concentration). One patient who had attempted suicide died 3 days after admission.

Decompression sickness

Of the 20 cases only 3 presented with joint pain alone. The rest had neurological symptoms or signs. Table 4 shows the sex breakdown and the number of treatments given.

TABLE 4

DECOMPRESSION ILLNESS

No. of cases		
Male	18	
female	2	
Total		**20**
No. of treatments		
Range	1-8	
Average	3.5	
One only	5	
5 or more	8	
Total		**69**

All patients received a RN Table 62 as the initial treatment. Five were given IV fluids. None received steroids or aspirin.

Follow-up at 1 and 3 months revealed that 3 still had residual problems. These 3 have ceased diving. At the 12 month follow-up 2 still had residual problems.

Table 5 lists the dive tables used. There was an increase in 1990 of the number of divers who were using computers compared with previous years.

Forty five percent of the dive profiles were within DCIEM tables, however, all of these were associated with accepted predispositions to DCS. These were:- heavy alcohol intake, multiple ascents, recent or concurrent illness and clinically a patent foramen ovale.

TABLE 5

DECOMPRESSION ILLNESS DIVE TABLES USED

Table used	Number	Inside DCIEM limits
None	4	1
Dive Computer	4	1
BS-AC/RNPL	1	1
Comex	1	1
PADI (old)	1	-
RDP	2	2
USN	5	3
Unknown	2	-

TABLE 6

DECOMPRESSION ILLNESS ASSOCIATED FACTORS

Alcohol	4
Previous DCS	1
Multiple dives	16
Multiple ascents	9
Flying after diving	4
Altitudeafter diving	1
Viral illness	2
Last dive deepest	6
Deep bounce dive	1

Table 6 lists the associated factors with all the cases of decompression sickness. There are some disturbing factors associated with some of the diver's diving habits; divers not using any recognised diving schedule, the deepest dive being the last dive of the day and deep bounce diving.

The shallowest recorded was 8 m, while the deepest was 56 m of sea water. The average depth was 20.5 m. The 8 m dive included 8 ascents to the surface.

Sixteen were local divers, therefore transportation to treatment was not a problem. However, only 6 divers presented for treatment within 12 hours of a problem being noticed. Table 7 lists the time from onset of symptoms to treatment.

TABLE 7

DECOMPRESSION ILLNESS BETWEEN DELAY SYPMTOMS AND TREATMENT

0 - 12 hrs		6
12 - 24 hrs		1
24 - 48 hrs		3
48 - 72 hrs		1
72 - 96 hrs		1
96-120 hrs		1
> 120 hrs		7
Mean	**89.6 hours**	
Range	**5.5 hours - 7 days**	

The qualification levels of the divers treated is listed in Table 8.

Osteoradionecrosis

Nine patients were treated. This involved a total of 235 treatments. All patients, the mandible was involved. All

TABLE 8

TRAINING LEVEL OF TREATED DIVERS

Basic	10
Advanced	3
Instructor	2
Not recorded	3
Commercial	2

Average years of diving 3.5 years.

were following radiation and surgery for head and neck carcinoma. Five still continued to smoke at the time of treatment. All had a good clinical result.

Osteomyelitis

Four patients were treated, involving a total of 125 treatments. Three patients had a successful clinical outcome which was judged by sinus and wound healing. The fourth patient's treatment continued on into 1991.

Gas gangrene and necrotising fascitis

Five patients with gas gangrene were treated. All received at least 6 treatments, one patient received 11. All were diagnosed at the time of surgery. All cases were post traumatic and Clostridium Welchii was isolated in all. One patient with necrotising fascitis was treated. The infection responded well to hyperbaric oxygen.

Idiopathic hearing loss

Two patients were treated for a total of 17 treatments. Both patients had a marginal increase in their hearing.

Venous stasis ulcer

There was no improvement in this patient.

Slow healing wounds

Threepatients were treated with poor results. All had very poor wound toilet despite constant encouragement by the Unit staff.

Spinal ischaemia

Two patients were treated with limited success.

Cyanide poisoning

The one patient poisoned by cyanide died.

Arterial gas embolism

One patient had an iatrogenic cerebral arterial gas embolism during coronary artery by-pass. Inspite of treatment the patient died.

Education

During the year two Medical Officers Diving Medicine courses were held. There were three Diving Medical Technicians Courses, two Hyperbaric Nurses courses and an Abalone "Shellers" course. Three Diving Safety Seminars were held.

Research

Research into Gas Embolism and Carbon Monoxide Poisoning continues. Dr Chris Acott is supervising the diving incident monitoring survey, which will reveal for the first time accurate figures of what are the common problems of recreational diving. It is hoped that the training agencies will be able to learn from these figures and then change their teaching so that more emphasis is given to avoiding the problems.

Publications

Williamson JA, King GK, Callanan VI, Lanskey RM and Rich KW. Fatal arterial gas embolism: detection by chest radiography and imaging before autopsy. *Med J Aust* 1990; 153: 97-100

Williamson JA. Case report: Inadvertent spinal subdural injection during attempted spinal epidural steroid therapy. *Anaesth Intens Care* 1990; 18: 406-408.

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1 Brotherhood JR, Budd GM, Hendrie AL, Jeffrey SE, Beasley FA, Costin BP and Zhien W. CO unlikely to be a hazard to bushfire fighters. *Med J Aust* 1989; 15(2): 18.

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ARTICLES OF INTEREST REPRINTED FROM OTHER JOURNALS

THE END OF DECOMPRESSION DIVING

Bob Halstead

During the past five years an incredible amount of theorizing, research and development has taken place trying to find ways for divers to enjoy multi-day, repetitive, multi-level diving and yet avoid getting decompression sickness. New decompression tables, some designed specifically for recreational divers, have been published and tested. Conferences have been held, papers written and some amazing progress made. The most significant part of this revolution has been the introduction of diving computers.

When the computers were first introduced they were criticized for several valid reasons. These criticisms were useful in that they forced manufacturers to conduct trials, which speeded the introduction of new and better programs and of computers with improved reliability. The process is far from over, but it is interesting that very few criticisms are heard these days from people who have taken the trouble to find out what the computers are trying to do, and how and why they work. If you are not sure yourself, I suggest you get hold of an excellent book "The Recreational Diver's Guide to Decompression Theory, Dive Tables and Dive Computers" by John Lewis and Karl Shreeves, published by PADI. It is true, however, that there is still no computer that can be followed exactly on most dives undertaken by recreational divers.

Now, before you get the wrong idea, I think that diving computers are the greatest thing to happen to diving since Archimedes. Depth gauges are noted for their abysmal inaccuracy and unreliability, including maximum depth needles that "creep", and a diver's loss of cerebral function at depth through narcosis makes it difficult for divers to get an accurate reading of their maximum depth. Measuring the bottom time is not always perfect either (forgot to set your watch again eh!). So I have to wonder at people who imagine a sport diver can take these largely imaginary numbers, feed them into a set of dive tables and come up with any meaningful information, even if they do know how to work the cursed things, which most divers do not. Nevertheless I thing that it is healthy for us to realize that computers are still limited in what they can do at their present stage of evolution. That is as of today, the 1st of November 1991. Tomorrow who knows?

Computers do measure, very accurately, the diver's depth and time and monitor this throughout the dive. They do produce a no-decompression limit (actually a no-stop limit), correctly calculated even if not necessarily applicable to every individual diver, and some provide decompression information if the limits are exceeded. They are very successful at giving meaningful information if the dives are multi-level, but only if the deep dives are done first in a repetitive sequence and the deepest part of the dive is reached early with the dive progressing into shallower water. There is still discussion as to the validity of multi-day calculations with some convincing arguments (but no data) that multi-day diving is not additive. The variation between computers depends on the criteria used in the program. Some programs are more conservative than others.

Now where we start to run into trouble with computers is:-

When we start to make repetitive dives that are deep or with a short surface interval;

When we realize that every dive should be ended with a decompression stop;

When we try to take into account the fact that, for largely unknown reasons, there is an enormous range of human susceptibility to getting bent.

Rearranging this slightly. Given that a particular diver's (you, for example) susceptibility to getting decompression sickness is possibly unpredictable and variable, and that neither computers nor modern tables accurately predict the correct no-stop limits for all dives, particularly deep, repetitive dives with short surface intervals, it is essential that every dive be terminated with a decompression stop, even if one is not required by the computer or by the tables.

These non-required stops are known as safety stops. They are nothing new. Sensible divers have been using them for years mainly because they understood that considerable uncertainty existed even if they had measured their depths and times carefully, and calculated their tables correctly. Also even short safety stops have been found to be incredibly effective in reducing bubble formation, particularly on deeper dives. For long shallow dives much longer safety stops are needed to have the same effect. Nevertheless safety stops are far more effective than controlling the rate of ascent. It seems that the rate of ascent does not actually matter except that fast ascents could lead to lung over-expansion and air embolism. The essential procedure is to avoid "decompression" dives but make a safety stop of at least three minutes at 5 m after every dive anyway, and to make longer stops after repetitive and/or long shallow dives.

But there is no universal agreement as to when a non-decompression (no-stop) dive becomes a decompression dive. To demonstrate this look at the short table below which gives the no-decompression (no-stop) limits according to various authorities for a single dive to 18 m.

French	75 mins	(no comment)

USN	60 mins
NAUI/PADI	55 mins
Spencer	52 mins
Bühlman	44 mins

So if you wish to avoid decompression diving and decide to dive to 18 m (60 ft) what do you do? What you have to do is choose a time between 44 and 75 minutes and have a bottom time less than the time you have chosen. You can pick the numbers you believe in, the religious approach, or pick a number out of a hat, the Vegas approach or phone Nancy Reagan or the Queensland Inspector of Diving, the mystical approach.

This is where I started to think that the world was going crazy. This is not the first time this has happened to me, if you remember it also happened when I saw divers who were perfectly safe by themselves being forced to make a dangerous dive by being appointed an incompetent or incompatible buddy, or when I saw divers exhausting themselves in a current by wearing a buoyancy compensator that could have seen better service as a sea anchor. Such is life, but see if you do not agree with me:

1 A decompression dive requires a decompression stop in order to make the dive "safe".

2 A no-decompression dive requires a decompression stop in order to make the dive "safe" (as discussed above).

3 All dives are either decompression or no-decompression (no-stop) dives.

4 Dives which require a decompression stop are called?

There it is. We have an unnecessary term in our vocabulary: "no-decompression dive". There should be no such thing. In fact I call upon all Governments to immediately ban the term. Henceforth all dives must be decompression dives.

This looks like I am just playing with words, but hang on a minute. All the tables and decompression meters available right now are obsessed with No-Decompression Limits, yet everyone in the business agrees that safety stops should be made, i.e. that the dives should be conducted as if they were decompression dives. My argument is that all computers and all tables should tell the diver exactly what to do. In other words they should include the safety stops in the program or table, and never give a hint that it is possible to ascend directly from any dive.

After all, if you are an instructor trying to teach a diver to make a decompression stop at the end of every dive, you are actually pretty silly immediately telling the diver to make sure that all dives are no-decompression dives!

It is just evolution at work again. We have learned that safety is improved if all dives are considered as decompression dives, that the concept of no-decompression diving is as useful as ping-pong ball in a snorkel, and that it is time to produce computers that tell use what stops we should be making after every dive.

It is still true, of course, that dives which are particularly deep or long or are repetitive will load us with exceptional quantities of nitrogen and require longer decompressions. We can set limits, not necessarily the old no-decompression limits, admitting that they are arbitrary, which we could call the "Recreational Diver Limits". This is an easy exercise. Authorities who publish tables can do as they do now and limit the information to acceptable dives, and computer manufacturers can build limit warnings into their computers as they do now.

What I hope to see from all this is:-

1 Computers that divers can actually follow.

2 A universal recognition that all dives require a decompression stop.

I think these would reduce the incidence of decompression sickness.

Reprinted, with permission, from Telita Cruises Newsletter November 1991

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ORCA INDUSTRIES SHUTS IT DOORS

Edge, Skinny Dipper, Delphi owners left in the lurch?

If the good news at Christmas was that you found an Orca computer under your tree, then the bad news is that if you ever need it serviced or repaired, you may find no one to help. On December 20th 1991, Orca shut down their operations and closed their doors, the victim of faulty products and a tough recession.

While Orca was the first American company to produce a workable computer and initially had the market nearly all to itself, frequent problems with all its models kept it from ever getting on secure financial ground.

The original Edge had transducer problems, leading to several bent divers. The Skinny Dipper was plagued with problems, not the least of which was that it leaked: an *Undercurrent* survey of readers found that as many as one-third of their Dippers had leaks severe enough to cut off the computer. The new Delphi had its problems, but having to recall the latest version of that device, the Delphi 3.0, further weakened Orca's financial condition. Add to this the recession and the lower than expected sales for the holiday season and, says Steven J. Carnevale, Orca president, "These factors have made it impossible to continue operating. We have decided to discontinue operations and proceed with an orderly liquidation of the company's assets."

Paul Heinmiller, Orca's chief engineer, told *Undercurrent* that they had hoped that normal sales would overcome the burden of the Delphi 3.0 recall. "Unfortunately the economy has not held up and our sales have been below a normal year. When Steve made his announcement on December 11th, it came as a surprise. Not that we didn't know that there were problems, but we felt that we would pull through."

Orca accepted no units for servicing or repair after December 11. Those that were not finished by the 20th will be returned, Heinmiller said.

Orca owners, most of whom have been fiercely loyal to their computers, even in the face of problems, are, for the time being, out of luck. With no independent repair services, they may never find anyone to handle their problems or provide replacements. Prior to closure, Carnevale looked for an infusion of capital, but to no avail.

The best Carnevale has to say to Orca owners now is that "Customers may be contacted some time next year regarding availability of sales and service if the assets of Orca are purchased by someone who intends to resume operation." If no buyer is forthcoming then Orca computers will become a technological dinosaur.

In addition to the problems Orca had with its equipment, the decision to remain solely a computer company may have also contributed to its demise. Companies with full lines of equipment, Dacor, USD, Oceanic, Beauchat, Tekna, Sea Quest and now ScubaPro, integrated their computers into their product line; during this economic downturn, the sale power of priced products helps keep them alive. But Orca, whose only product is a luxury to most divers, learned too painfully that in a recession, the purchase of a luxury item can be easily postponed, especially for divers deciding to postpone travel.

Furthermore, when Orca was the sole producer of computers, both active and new divers were their market. Today, most divers who have been active for a while have already purchased their computers, leaving the primary market to newly certified divers and those who have been at it for a short time.

So while more and more companies entered the market, competing both in price and product, Orca's share dropped dramatically.

For the past few months, rumours were afoot that Orca was in trouble. Though those rumours were denied, the hand writing was on the wall. It was not a matter of whether Orca would fold, but when. Now we know the answer.

And we also know that Orca, although the first victim in this recession, may indeed not be the last.

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The address of UNDERCURRENT is P.O. Box 1658, Sausalito, California, 94966, U.S.A.

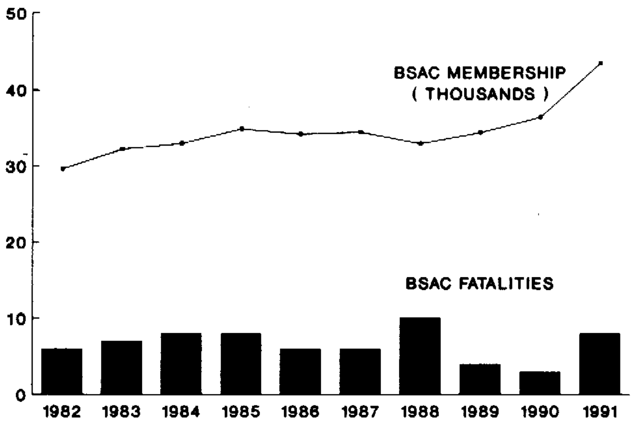
BE PREPARED!

Chris Allen

Analysis of diving incidents in 1991 highlights the need for divers to plan for every eventuality.

Following my 1990 report, which recorded one of the lowest number of sports diving fatalities for several years, it is disappointing to have to begin my review of the 1991 diving incident statistics with the news that, in contrast, this year has been one of the worst since 1973 in terms of fatalities, with 17 being recorded. Of these, 8 were BS-AC members.

BSAC FATALITIES AND MEMBERSHIP 1982-1991

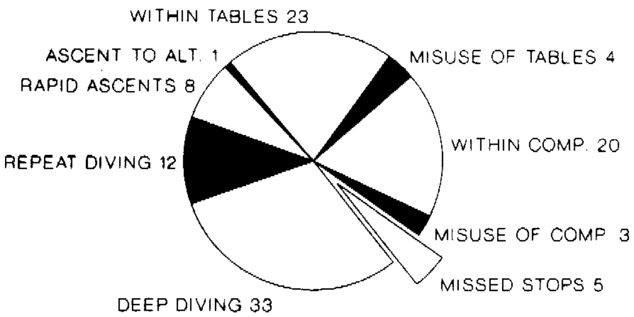


When the fatal accidents are considered in more detail, we find that two divers died on solo dives and separation was a factor in a further six cases, thus underlining the crucial importance of the buddy system for safe diving.

One area of particular concern this year is that four of the deaths (none of which involved the BS-AC), occurred on dives or training courses organised by dive schools.

There is rather better news when we look at the recorded cases of decompression sickness, where the reduction from the record number of cases in 1989 (137) has been maintained. Last year I reported a sharp drop from 137 to 80 cases, but had to acknowledge that my data capture was not as good as it ought to have been, because of a lack of information from the Institute of Naval Medicine (INM). This year, for the first time, the INM have been operating a central database of decompression incidents to which all the UK recompression facilities have been encouraged to contribute, using a standard reporting form. This has made it easier for them to supply us with much more complete information, which in turn means that our data is more accurate.

DECOMPRESSION SICKNESS ANALYSIS - 1991



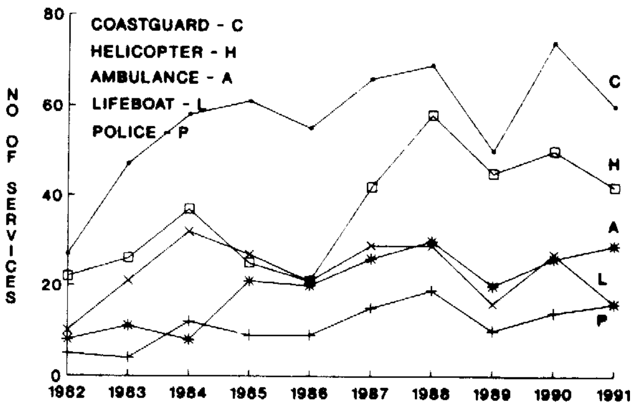
TOTAL NO. OF CASES = 100

This year a total of 100 cases of decompression sickness have been recorded, which reinforces my belief that the peak figure of 137 cases, seen in 1989, was a reflection of record levels diving performed that year as a result of the exceptionally good summer, rather than a sign of continuing upward trend as some people were claiming.

Overall, the incidence rate of decompression sickness among sport divers in the UK appears to be remaining fairly constant with one case in every 10,000 to 15,000 dives. Some 40% of these cases occur within the limits of accepted decompression tables. Such cases can often prove to have a medical explanation. However the risk of decompression sickness is not evenly distributed, and as everyone should be aware, the risk increases significantly with deeper dives and with repeat diving. This year for example 65% of the recorded cases of decompression sickness were on dives deeper than 30 m.

Cases of lost divers always tend to attract publicity and media attention, and that was certainly the case this year. Although the actual number of cases was not particularly high, there were some dramatic examples. Such cases inevitably impose a significant demand on search and rescue resources and do nothing to enhance the reputation of the sport.

DIVERS' USE OF EMERGENCY SERVICES



The most extreme case of all this year involved two divers who were reported missing in the Farne Islands. An extensive air and sea search was mounted, involving helicopters, lifeboats, coastguard units and other vessels. After seven hours, the search was suspended overnight and resumed the following day. The two divers, who were adrift for more than 23 hours, were not located until they managed to get themselves ashore several miles down the coast and made contact with the Coastguard.

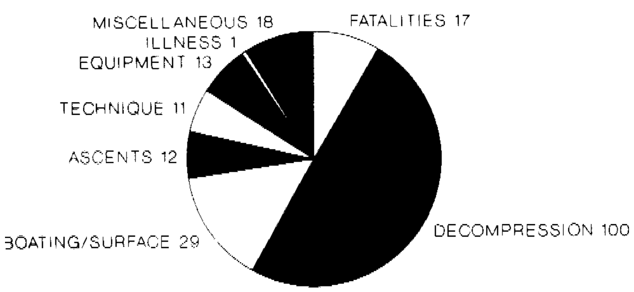
Another pair of divers, who surfaced earlier than expected, were unable to attract the attention of their cover boat which was only about 100 m away. They drifted away quickly on the surface and in spite of an extensive air and sea search and the fact that they fired several "mini-flares", they were not picked up for more than six hours. They were eventually picked up well outside the designated search area.

When looking at the location such incidents, the Skomer area seems to have experienced more than its fair share this year, and it seems clear that many divers visiting this are seriously underestimating the local tidal conditions. It was there for example that another pair of divers also drifted on the surface for six hours, covering a distance of more than ten miles, after they had surfaced out of sight of their cover boat. Surface marker buoys had not been used because the water was calm and there was no obvious current. However the divers experienced strong currents towards the end of their dive, and these swept them rapidly out to sea when they surfaced.

The remedy for the majority of such cases is very obvious, use a surface marker buoy (SMB). Although you will hear people complain about the inconvenience of using an SMB, it is my experience that they either have not thought their equipment through adequately, or have simply not mastered required skills. Providing a proper reel and buoy arrangement is used, there should be little or no effect on the diver. Unless you are diving in a very localised areas such as on a wreck, or there is a particular risk of the buoy line becoming entangled, the benefits to the cover boat in knowing exactly where the divers are far outweigh any slight inconvenience to the divers themselves.

As usual, boating and surface incidents form the second largest group of reports after decompression sickness. In one case, a party of divers on a hard boat all entered the water together because the tide was increasing too rapidly to allow time for two "shifts". The very last diver in the party became entangled with the ladder as he had jumped in and, unseen by the boat's skipper, was dragged along underwater as the boat moved off. The force of the wash ripped his mask and mouthpiece off and he very nearly drowned. When the skipper's attention was drawn to the problem he was unable to do anything. Fortunately two divers from another party nearby were able to cut the casualty free and lift him back into the boat where he was resuscitated. The importance of maintaining sufficient cover in the boat to react to an emergency and, if necessary, to effect a rescue cannot be over-emphasized.

DIVING INCIDENTS BREAKDOWN - 1991



Still on the surface, an unusual incident was reported when a diver lost his knife overboard from an inflatable during the trip to the dive site. The knife was still attached by a curling telephone-type cord and bounced along behind, first of all puncturing one of the tubes of the inflatable, before re-entering the boat and striking two of the divers. Although no serious damage or injury was caused, I am aware of far more incidents being caused by these cords than by divers losing their knives and my advice would definitely be not to secure your knife in this way.

The BS-AC Incident Reporting Scheme receives reports not just from Britain, but also from our branches overseas. Reports of shark attack are fortunately very rare, but this year two BS-AC members in Kenya suffered serious injury when they were attacked by a shark whilst performing a circular search exercise in low visibility. Neither of them saw the shark before they were hit. Both sustained serious leg injuries and unfortunately one subsequently had to have his leg amputated below the knee.

Among the incident reports involving equipment are two which emphasise the need not underestimate the risk from handling compressed air cylinders. We tend to take them for granted because they rarely give problems, but the consequences of failure can be dramatic. In the early part of this year, a diver's pony bottle exploded whilst being filled, causing severe damage to the compressor room and injuring three people. It had last been tested four years previously and on examination was found to be severely corroded.

The second incident involved a cylinder which was overcharged at a dive shop. The cylinder was an ex-fire brigade cylinder with a working pressure of 135 bars. It was charged to 240 bars by a fellow customer who was "helping out". The cylinder's test pressure was only 180 bars and a serious accident could easily have occurred. The lesson is clear. Cylinders should only be filled by competent operators who ensure that they only fill cylinders which have a current test certificate.

When analysing Incident Reports, I am often struck by the number of times in which the consequences of an incident have been made more severe by the absence of suitable backup equipment or an appropriate contingency plan.

Often in such cases the general planning and conduct of the dive was perfectly acceptable, but when something went wrong, usually only a small thing, there was inadequate provision to deal with the situation.

Another lost-diver case illustrates just how easily things can go wrong when something unexpected happens. A pair of divers ascending up the shot line after a dive to 48 m found that the shot rope buoy had been pulled under, and had collapsed and sunk to 25 m. Consequently, they were forced to perform their required decompression stops in mid-water, and whilst doing so they drifted a significant distance in the tide. When they surfaced they were unable to attract the attention of their cover boat and drifted away. A large scale search involving four lifeboats and two helicopters ensued and they were eventually picked up about three and half hours later.

In this example, if the divers had been carrying a delayed surface marker buoy they would have been able to perform their correct decompression stops, whilst at the same time indicating to their surface cover exactly where they were. Once on the surface, had they had an alternative means of attracting attention, such as a flag or a flare, it might have made all the difference.

Planning for such contingencies is something which experienced divers do, almost without thinking. A simple way to test whether your equipment and dive plan can cope with an unexpected problem is to pose a few "What if" questions.

Try the following examples to start with. What if I surface a long way from the cover boat, how will I attract their attention? What if I do not find my way back to the shot rope for some reason, how will I control my decompression stops effectively? What if we need to recall the divers/ contact the Coastguard administer oxygen/change a spark plug, do we have the necessary equipment?

Ideally every diver should have a secondary air supply, own a SMB and carry a backup means of attracting attention on the surface. Every dive boat should have a VHF radio and carry oxygen. On every planned decompression stop dive, spare air should be available and each pair should carry a delayed SMB.

Many of those directly involved in this year's incidents have learnt their lessons the hard way. They now know how to prevent them recurring or how to deal more effectively with the situation should it arise again. By studying the full 1991 Diving Incidents Report, hopefully the rest of us can also learn from their experiences and implement the solutions, before we encounter the problems.

Reprinted by kind permission of the Editor, from DIVER, 1991; 36 (12)December: 43-44

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GLEANINGS FROM MEDICAL JOURNALS

The following articles have come to the notice of the editorial staff and these notes are printed to bring them to the attention of members of SPUMS. They are listed under various headings of interest to divers. Any reader who comes across an interesting article is requested to forward the reference to the Journal for inclusion in this column.

MARINE ANIMAL INJURIES

Two-fathom hickey.

Falcone RE and Miller AP. *New Eng J. Med* 1991; 325(7): 521-522.

Letter

Describes hand injury due to suction, partial-thickness contusion-avulsion (hickey), following attempted hand feeding a stingray by a diver. Appropriate treatment described. Moral: Beware of feeding "tame" stingrays.

Sudden death in a child following jellyfish envenomation by *Chiropsalmus quadrumanus*.

Bengston K, Nichols MM, Schnadig V and Ellis MD. *J A M A* 1991; 266: 1404-1406.

Abstract

Sudden death following coelenterate envenomation is not uncommon in Australia where the Pacific box jellyfish is indigenous. However, few cases of sudden fatal reactions have been reported in the Northern Hemisphere, and those that have occurred have all been attributed to the Portuguese man-of-war, *Physalia physalis*. We report the case of a child who died within 40 minutes of accidental envenomation with tentacles of a jellyfish, *Chiropsalmus quadrumanus*, and describe the findings at autopsy. This coelenterate may be of special danger to small children.

Stonefish and stingrays - some notes on the injuries that they cause to man.

Cooper NK. *J R Army Med Corps* 1991; 137: 136-140.

A review is presented of past and present records of injuries caused by these fish with particular reference to the occasional fatalities that have ensued.

The wide geographical range of species of both types indicate a variety of current Service postings where such injuries can be sustained.

The pharmacological actions of the venoms of both types are summarised as far as they are known. Modern lines of management are described which stress the need for through debridement of these injuries.

Historical vignette - the death of an Australian army doctor on Thursday Island in 1915 after envenomation by a stonefish.
Cooper NK. *J R Army Med Corps* 1991; 137: 104-105.

Discusses stonefish envenomation and queries the diagnosis of stingray injury on the doctor's tombstone.

RECREATIONAL DIVER TRAINING

Economic considerations in promoting scuba refresher courses: an Australian view.
Wilks J. *Sources* 1991; September/October: 58-60.

A paper addressed to NAUI Instructors drawing attention to the fact that a large percentage of the divers surveyed would be interested in undertaking refresher causes to upgrade their skills.

Undersea and Hyperbaric Medical Society Annual Scientific Meeting 1991 Selected Abstracts

RECREATIONAL DIVERS

How well do they do it: a survey of sport divers' ability to work decompression problems.
Hill RK Jr. Undersea Biomed Res 1991; 18 (Supp): 51.

The best decompression schedule is unsafe if not used properly, and little work has been done to evaluate the ability of sport divers to work out decompression problems once they complete their training. During SEASPACE 88, the largest sport diving meeting in America, a questionnaire and 5 decompression problems were distributed, with 2,576 completed forms returned. Only 46% of those completing the 5 questions had all correct representing 54% of female respondents and 46% of the males (ANOVA p= 0.00005). Which training agency, level and date of more advanced training, and type of specialty training were all significantly different for the group correctly answering all the questions (p= or< 0.001). Not found to be significantly different were the age of the diver, the date of initial training, the certifying agency of the most advanced training, nor the date of the last training. These findings have implications for both diver training and the safety of use of diving computers.

From the Hyperbaric Medicine Department, Our Lady of the Lake Regional Medical Center, Louisiana, U.S.A.

Evidence of altered liver function in a group of amateur scuba divers following a diving holiday.
Doran GR. *Undersea Biomed Res* 1991; 18 (Supp): 46-47.

In the light of previous findings of altered liver function among professional deep saturation divers a range of biochemical blood tests were performed on 9 experienced amateur scuba divers (8 male; aged 30-60 years) before and immediately after a 12 day diving holiday to Eilat, Israel in March 1989. The average total number of dives undertaken was 18; to depths ranging from 6 to 50 msw, with an overall average depth of 20 msw. With the exception of one male all the divers continued to consume alcoholic drinks while on holiday. Significant post holiday climbs were detected in their plasma activities of isocitrate dehydrogenase (P<0.05), alkaline phosphatase (P<0.01) and acid phosphatase (0.05). The levels of the plasma glycoproteins thyroxine-binding globulin and fibronectin also rose (P<0.01), together with the complement C_3, fraction (P<0.02). No significant post-holiday changes were identifiable overall in the activities of the transaminases (AST,ALT), g glutamyl transferase (GT) or cholinesterase, nor in their plasma bilirubin or g, acid glycoprotein levels. While among the male divers the changes were generally moderate, those evident in the only woman in the group were pathologically severe (including raised AST, ALT and gGT), such as would characterise a mild hepatitis. However, subsequent serology failed to identify any common infective aetiology. The fact that, apart from the case of the woman diver, no elevation of ??GT was evident, coupled with the fact that changes were equally apparent in the male who abstained, argues against these disturbances being attributable to "excessive" alcohol consumption. Overall the results confirm that some significant alterations in divers' liver function tests may be brought about by repetitive shallow diving and that exposure to very high ambient pressures (>6 ATA) is not a prerequisite. The possibility that women may be more severely affected than men requires further careful review.

From the Department of Chemical Pathology, Charing Cross and Westminster Medical School (University of London).

Clinical evaluation of repetitive deep diving by recreational divers on the wreck of the Andrea Doria.
Blumberg L and Myers RAM. *Undersea Biomed Res* 1991; 18 (Supp): 50.

Ten male recreational divers were clinically evaluated over a 3 day period as they made repetitive deep dives [>200 fsw] with compressed air to the wreck of the Andrea Doria in the North Atlantic Ocean. Diving profiles were recorded and verified while divers were followed clinically for signs/symptoms of decompression sickness, air embolism, and/or other diving maladies. Ulltrasonic Doppler testing was used to assist in objective analysis. The divers ranged in age from 27 to 47 years old, weight from 145 to 285 lbs., previous logged dives from 50 to 1250, and diving depth from 187 to 240 fsw. During the 3 day study period the ten divers performed a total of 49 dives. None of the divers exhibited any signs/symptoms of decompression sickness or air embolism. Intravascular bubbling was detected in only 2 divers and only one diver attained a Spencer rating of 2 on any dives. The incidence of positive Doppler testing was 4.3%. Nitrogen narcosis was not a significant problem for any diver. The equipment used by each diver was extensive and included multiple back-up devices and systems. Eight divers carried at least 1 dive computer, while 1 carried 3 (in case the other 2 failed). With water temperature at depth of 46 °F, all divers wore drysuits except one.

All divers had trained for these deep dives by performing progressively deeper dives [>130 fsw, 39 m] several weeks to months prior to attempting these truly deep dives. Although not recommended for the average diver, repetitive deep diving by experienced recreational divers, with appropriate equipment and training, led to no incidence of decompression sickness, air embolism, or other diving maladies during this study.

From the Department of Hyperbaric Medicine, Maryland Institute for Emergency Medical Services Systems, University of Maryland, Maryland, U.S.A.

VESTIBULAR PROBLEMS

Vestibular disease in dive accident victims in Hawaii.
Arnold AA and Tolsma KA. *Undersea Biomed Res* 1991: 18 (Supp); 45-46.

Between 1983 and 1990, 315 diving accident victims were treated at the Hyperbaric Treatment Center. Of those, a retrospective analysis identified 37 (12%) cases having vestibular symptomatology. Twenty-seven were diagnosed as having Vestibular DCS (VDCS), 9 as having Inner Ear Barotrauma (IBE), and 1 as having AGE. Of those with VDCS, 16 (60%) had associated DCS syndromes, and 11 (40%) had purely vestibular symptoms. IEB included Perilymphatic Fistulae, and Cochlear Trauma. The diagnoses of IEB and VDCS were made, for the most part, on clinical grounds. Of the many examination modalities used, some are emphasized by the physicians at HTC. Despite detailed evaluation of the patient, it was often difficult to distinguish between dysbaric disease and IEB, and therefore some patients with IEB received a trial of recompression therapy. It was noted that these patients did not have worsening of their symptoms. It is recommended that a full and careful evaluation be performed, though it should not interfere with the prompt initiation of recompression therapy. If doubt as to the diagnosis exists, it is better in our experience to err on the side of recompression, since worsening of IEB symptoms, though a theoretical concern, did not occur in our series.

From the University of Hawaii, Hyperbaric Treatment Center, Honolulu.

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*Overseas courses and meetings appear on page***

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