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SPUMS

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OBJECTS OF THE SOCIETY

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

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The Society's financial year is January to December, the same as the Journal year.

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Those interested in joining SPUMS should write to

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Photographs should be glossy black-and-white or colour. Slides should be converted photographs before being sent. 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.

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The preferred length for 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, facsimile numbers and e-mail address of the corresponding author, should be supplied with the contribution. No more than 20 references per major article will be accepted. Accuracy of the references is the responsibility of authors. Acknowledgments 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).

References

The Journal reference style is the "Vancouver" style, printed in the Medical Journal of Australia, February 15, 1988; 148: 189-194. In this system 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

There should be no full stops after the reference numbers. There should be a space after the semi-colon following the year and another after the colon before the page number and no full stop after the page numbers. The Journal uses two spaces after a full stop and before and after the journal name in the reference. Titles of books and quoted journals should be in italics.

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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.

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SPUMS ANNUAL SCIENTIFIC MEETING 2001

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DIVER EMERGENCY SERVICE
PHONE NUMBERS
1-800-088-200 (Australia)
+61-8-8212-9242 (International)

The DES number 1-800-088-200 can only be used in Australia.

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.

DIVING INCIDENT MONITORING STUDY (DIMS)

DIMS is an ongoing study of diving incidents. An incident is any error or occurrence which could, or did, reduce the safety margin for a diver on a particular dive. Please report any incident occurring in your dive party, but do not identify anyone. Most incidents cause no harm but reporting them will give valuable information about which incidents are common and which tend to lead to diver damage. Using this information to alter diver behaviour will make diving safer.

To obtain Diving Incident Report forms write to

DIMS,
GPO Box 400, Adelaide, South Australia 5000.

PROJECT PROTEUS

The aim of this investigation is to establish a data base of divers who dive or have dived with any medical contraindications to diving. At present it is known that some asthmatics dive and that some insulin dependant diabetics dive. What is not known is how many. How many with these conditions die is known. But how many dive safely with these conditions is not. Nor is incidence of diving accidents in these groups known.

This project is under the direction of Dr Douglas Walker and Dr Mike Bennett. The investigation has been approved by the Ethics Committee of the Prince of Wales Hospital, Randwick, approval number 01/047.

If you are in such a group please make contact. All information will be treated as CONFIDENTIAL. No identifying details will appear in any report derived from the data base.

Write to Project Proteus
PO Box 120, Narrabeen, New South Wales 2101, Australia.
E-mail <diverhealth@hotmail.com>

The Editor's Offering

We hope that 2002 has started well for our readers. This issue contains some interesting case reports. Dr Robert Noll presents two unusual late presentations of carbon monoxide poisoning. Both patients gassed themselves in their cars. One was rescued and taken to hospital unconscious where she improved with hyperbaric oxygen therapy (HB_2OT) and was discharged but over time developed mental changes. The other did not go to hospital until days later. Both were restored to normal life by HBO_2T. Dr Chris Acott's patients were not so lucky. They died on the surface after going diving. They shared an unusual finding, each had a badly bitten tongue. Neither would have had the real cause of their death discovered without Dr Acott's co-operation at the post mortem. In both cases the history at the time of their rescue was inaccurate and this misled the investigators. Another interesting case report is on page 60 and is reprinted by kind permission of the BMJ Publishing group. Yet another appears in the Letters to the Editor. Both of the latter were doing well at last report.

Diving and Hyperbaric Medicine (DHM) is a steadily growing speciality. The Undersea and Hyperbaric Medical Society (UHMS) has been negotiating with the US Medical Boards, which control specialist registration, for some years and two years ago had success in establishing an examination for sub-speciality registration. However this is only open to US registered specialists. On page 10 we reprint a recent paper published in the UHMS Newsletter *Pressure*. On page 11 we publish a paper about the position of the Australasian search for a higher qualification, a logical successor to the SPUMS Diploma of Diving and Hyperbaric Medicine (DDHM) which is an indicator of at least six months full time, or equivalent part time, devotion to DHM. Thanks to the energy of Dr Robert Wong the Australian and New Zealand College of Anaesthetists (ANZCA) established a DHM Special Interest Group (SIG). It Executive has worked hard to produce a syllabus and educational standards which would allow the DHM SIG to convince the College to issue Certificates of DHM training. At the time of writing the final stage, of a meeting of the Certificates Committee, in expected within months. This will mean that DHM practitioners will have an examination marked career path.

As usual we carry papers from last year's Annual Scientific Meeting (ASM). This year's meeting will be in Vanuatu, only a hop, skip and a jump from Queensland. The theme of the meeting is Diving and Travelling in Remote Localities, a subject which should interest all members as everyone has to travel to leave Australia and much of the best diving is in remote localities. Our Guest speaker is Dr Trish Batchelor, who is National Medical Director of The Travel Doctor, an organisation which has branches in each State capital. The workshop will be about morbidity and mortality associated with diving equipment. All readers who have not yet registered to attend the ASM should contact the SPUMS Home page (page 8) for further details of what should be a exciting and enjoyable meeting.

Now that the South Pacific Underwater Medicine Society Journal is indexed by EMBASE, the European equivalent of Medline, we hope that the days of reprinting Diploma theses from other Journals are over. Dr Bennett's research on bubbles in tear films after diving appeared in the only issue of Undersea and Hyperbaric Medicine to leave the printing press before 2001 ended. Readers will find this multi-author presentation on page 54. Those who attended the 2000 ASM at Castaway Island and volunteered to have their bubbles counted can see their pooled results in print.

Book reviews are often interesting. For those with aspirations to advise diving organisations the *NOAA Manual* has been assessed by John Pennefather (one third of the authors of Diving and Subaquatic Medicine). Carl Edmonds (another third) has reported on a diver's biography and Steve Goble comments on *Diving into Darkness* and reviews James Francis' *Danger's Hour*. He recommends both. The UK Historical Diving Society's 2001 conference proceedings have also been reviewed and are, like Danger's Hour, almost essential reading.

James Francis leads readers through the perils of breathhold diving, one of his presentations in Madang, and discusses the causes of unconsciousness in divers. Robyn Walker discusses the lung assessment of those undergoing submarine escape training. Chris Acott and our Education Officer, David Doolette present a paper on simulating the effects of near-drowning on decompression sickness (DCI). They estimate the risks of DCI in those who near drown after various dives. The rise in risk is yet another reason to ascend slowly, to avoid unconsciousness during ascent, and to drop one's weight belt when in trouble on the surface, to avoid near-drowning.

The team from the Prince of Wales Hospital Diving and Hyperbaric Unit present the results of their investigation of the effects of hyperbaric oxygen on the lung function of non-smokers and of smokers. Contrary to the expectations of some there were only minimal differences between the two groups.

SUBSCRIPTION REMINDER

If you have not renewed your 2002 membership please do so immediately as the June 2002 issue will only be sent to financial members.

This year's subscription is the same as last year $Aust 121.00 for members and corporate members and $Aust 60.50 for Associates.

ORIGINAL PAPERS

COMPARING PERSONALITY TRAITS OF NAVY DIVERS, NAVY NON-DIVERS AND CIVILIAN SPORT DIVERS

Charles van Wijk

Key Words

Health, occupational diving, recreational diving, personality

Abstract

This study compared 28 South African Navy divers, 28 South African Navy non-divers and 28 civilian sport divers, using the 16 Personality Factor Questionnaire. Four traits appeared to be prominent descriptors of the SAN divers, namely enthusiasm, adventurousness, confidence and group orientation. The navy divers differed from the navy non-divers with higher scores for ego strength, and were more adventurous and tough minded. In comparison to the civilian sport divers, they were less assertive, had higher superego scores, were more practical, shrewd, group orientated and had a higher self-sentiment. Possible implications of the findings are discussed.

Introduction

Research on the personality of military divers have described them in terms of biographical variables,[1] psychiatric "disturbances",[2] psychopathology,[3,4] anxiety,[5-7] aggression,[6] personality traits,[5,8] locus of control,[5] personality styles,[9] and neuropsychological profiles.[10,11]

These findings suggest that navy divers exhibit more psychiatric disturbances than other sailors,[2] although different studies have found different results using the MMPI with navy divers.[3,4] Both navy and recreational divers are less anxious,[5-7] more aggressive in social situations,[3,6] and tend to seek adventure and thrills.[5,12] Navy divers show a more internal locus of control,[5] and have lower scores on measures of social contact.[5] Some neuropsychological impairment has been found in abalone divers.[10,11] On the Millon Index of Personality Styles, 5 styles appeared descriptive of divers, namely Enhancing, Modifying, Individuating, Thinking and Controlling.[9] Personality traits associated with divers on the 16 Personality Factor Questionnaire (16PF) were Group dependency, Enthusiasm, Adventurousness, and Confidence.[13]

Much of the published research has been done on US Navy Divers, and only one study reported on divers in the South African Navy (SAN).[13] This study found SA navy divers to be more social and group orientated, when compared with studies from other navies. The South African study raised a number of questions. Firstly, to what extent are their different social orientation due to sampling; secondly, as the SAN divers shared many factors on the 16PF with SAN submariners, to what extent do they actually differ from other navy personnel; and thirdly, since the literature suggests that naval and recreational divers share a number of traits (lower anxiety, higher aggression, adventure seeking), to what extent can the description of navy divers can be generalised to other divers.

The study reported here is a follow up of the study on SAN divers. It aimed to answer these three questions:

a will the same results be found in a different group of SAN divers,
b do navy divers differ from general navy sailors, and
c can personality traits of navy divers be typical of those of civilian recreational divers?

Methodology

TEST USED

16 Personality Factor Questionnaire (16PF) was administered to all participants.[14] The 16PF was developed by Cattell and is a measurement of personality described by 15 personality factors and one mental ability factor. Each factor on this self-report instrument is scored on a bipolar scale, indicating a personality trait. Factor A is reserved vs warm hearted. Factor B is low intelligence vs high intelligence. Factor C is high ego strength vs low ego strength. Factor E is submissiveness vs dominance. Factor F is sombre vs enthusiastic. Factor G is low superego vs high superego. Factor H is timid vs adventurous. Factor I is tough-minded vs tender-minded. Factor L is trusting vs suspicious. Factor M is practical vs imaginative. Factor N is artlessness vs shrewdness. Factor O is untroubled adequacy vs guilt proneness. Factor Q_1 is conservatism vs radicalism. Factor Q_2 is group orientation vs self-sufficiency. Factor Q_3 is low self-sentiment vs high self-sentiment, and factor Q_4 is low ergic tension vs high ergic tension (referring to irrational worry and anxiety). The South African edition of the 16PF that was used is standardised for non-clinical populations and has previously been used in the South African context for a wide range of personnel selection applications and vocational guidance. At present it is mostly used for research purposes.

PARTICIPANTS

The participants were recruited through visits to the various units at the naval base and through visits to two sport diving clubs. Each time a short briefing about the research was given, after which the sailors and sport divers were invited to participate. Participation was voluntary, and participants received no financial benefit. Naval personnel were given time off their work to complete the questionnaire and the sport divers completed theirs during a club evening. In all cases the testing was administered in groups (ranging from 9 to 30 in size), with participants sitting at separate desks in a quiet room. Twenty-eight non-navy diver-profiles were collected at the dive clubs. Thirty navy non-diving profiles were collected, but two had missing data and were discarded. This represented 84% of the group invited. The profiles of the first 28 navy divers who volunteered to do the test, 52% of those invited, were collected.

Navy diver group

Twenty-eight SA Navy divers on active duty participated in the study. All were qualified as clearance divers, and each diver had 12 years of formal schooling. They were all medically and psychologically fit for military diving. The mean age for the 27 men and one woman was 25.57 years (see table I). On average they had been involved with military diving for 4.5 years.

Navy non-diver group

Twenty-eight sailors comprising of shore-based protection service personnel and ship-based technical personnel acted as a comparison group. The 23 men and 5 women were all attached to the same naval base as the divers. None of them had any diving background. Their mean age was 26.39 years, and each sailor had 12 years of formal schooling. There was no significant difference in the time spent in the navy when compared with the divers.

Civilian recreational diver group

Twenty-eight civilian sport divers from 2 local diving clubs formed the non-navy recreational diver comparison group. The 4 women and 24 men had a mean age of 24.14 years, and had been, on average, involved with sport diving for 3.6 years. Their qualifications ranged from Open Water I to Divemaster and none of the sport divers had any military background. They had on average 4 years of tertiary education.

A certain amount of (self) selection took place involving individuals in the 3 groups studied. Navy divers are selected before training and can be expected to already constitute a defined group. As selection forms an integral part of SA Navy diving, it needs to be factored in when comparing to other groups. Recreational diving is an equipment dependant sport and usually only individuals from economically better off communities participate in scuba diving.

The navy divers had a mean age of 25.57 years. There was no significantly age difference between them and the non-diver group (mean =26.39), nor with the recreational divers (mean = 24.14). The navy divers and non-divers had the same years of service in the navy, and the navy divers had been involved in diving for slightly longer than the civilian sport divers (navy divers = 4.5 years, sport divers = 3.6 years). The navy divers included one woman (3.6%), the non-diver naval group had 5 women (17.9%) and the civilian divers 4 women (14.3%).

STATISTICAL ANALYSIS

The scores were analysed using *STATISTICA '95*. The descriptive statistics for age are shown in table 1 and naval divers' 16PF profiles are shown in table 2. The navy diver group is compared with the navy non-diver group in table 2 using t-tests for independent groups. T-tests for independent groups were also used to compare the navy divers with the recreational divers.

TABLE 1

DESCRIPTIVE STATISTICS FOR AGE

Group	Mean	SD	Min	Max	No
Navy divers	25.57	2.95	20	36	28
General navy	26.39	3.14	20	33	28
Sport divers	24.14	2.90	20	28	28

Results

Table 2 presents the means and standard deviations for the 15 personality factors. The 16PF pattern for the navy diver group is one of enthusiasm (F^+), adventurousness (H^+), confidence (O^-) and group orientation (Q_2^-).

Table 3 presents the comparative scores between the navy diver and navy non-diver groups. The navy diver group had higher ego-strength (C^+), were more enthusiastic (F^+) and tough minded (I^-) than their non-diving comrades.

The comparative scores for the navy diver and civilian diver groups are presented in table 4. The navy divers showed less dominance and assertiveness (E^-), had a higher superego (G^+), were more practical (M^-), more shrewd (N^+), more group orientated (Q_2^-), and had a higher self-sentiment (Q_3^+).

Discussion

The 4 prominent traits of the navy divers replicate what has been found before with SAN divers, even though the present sample size was small. A discussion of the traits and their implications can be found in Van Wijk and Waters.[13] It is possible that the difference found between SA and US navy divers on sociability may indicate a social

TABLE 2

MEANS AND STANDARD DEVIATIONS FOR 16PF FACTORS

Factor	Navy diver group Mean	Navy diver group Standard deviation	Mean of norm group
A	5.29	1.86	5.5
C	6.75	1.51	5.5
E	6.21	1.79	5.5
F*	7.32	2.13	5.5
G	6.21	1.64	5.5
H*	7.07	1.12	5.5
I	4.75	2.17	5.5
L	4.21	1.93	5.5
M	4.75	1.04	5.5
N	5.64	2.13	5.5
O*	3.96	1.17	5.5
Q_1	6.36	1.83	5.5
Q_2*	3.32	1.59	5.5
Q_3	6.79	1.75	5.5
Q_4	4.46	1.73	5.5

(* $p < 0.05$)

TABLE 3

COMPARATIVE SCORES FOR NAVY DIVERS AND NAVY NON-DIVERS

Factor	Mean navy diver	Mean navy non-diver	t-value	p-value
A	5.29	5.82	-0.99	0.3271
C*	6.75	5.36	3.13	0.0028*
E	6.21	5.43	1.66	0.1029
F*	7.32	5.07	4.44	0.0000*
G	6.21	6.32	-0.26	0.7977
H	7.07	6.75	0.83	0.4096
I*	4.75	6.14	-2.42	0.0190*
L	4.21	5.32	-1.99	0.0521
M	4.75	5.18	-1.14	0.2604
N	5.64	5.89	-0.50	0.6173
O	3.96	4.46	-1.43	0.1574
Q_1	6.36	5.54	1.96	0.0557
Q_2	3.32	4.21	-1.81	0.0765
Q_3	6.79	7.36	-1.26	0.2126
Q_4	4.46	5.07	-1.40	0.1682

(* $p < 0.05$)

TABLE 4
COMPARATIVE SCORES FOR NAVY DIVERS AND CIVILIAN SPORT DIVERS

Factor	Mean navy diver diver	Mean civilian diver	t-value	p-value
A	5.29	5.00	0.52	0.6064
C	6.75	6.29	1.28	0.2049
E*	6.21	7.93	-4.16	0.0001*
F	7.32	6.57	1.40	0.1672
G*	6.21	4.93	3.25	0.0020*
H	7.07	7.21	-0.26	0.7933
I	4.75	4.50	0.44	0.6605
L	4.21	4.64	-0.68	0.4986
M*	4.75	5.57	-2.30	0.0251*
N*	5.64	4.50	2.39	0.0206*
O	3.96	3.14	1.83	0.0728
Q_1	6.36	6.86	-0.97	0.3375
Q_2*	3.32	5.21	-3.96	0.0002*
Q_3*	6.79	5.57	2.69	0.0094*
Q_4	4.46	5.07	-1.22	0.2273

(* $p < 0.05$)

orientation typical to South African navy divers and is not just a function of sampling.

When compared to other navy personnel not involved in diving, differences emerged on 3 factors. This is in keeping with previous research which found that divers differed from submariners on 2 factors of the 16PF [13], and from a group of general navy personnel on some anxiety and hostility scores.[16]

Factor C (ego-strength) refers to emotional stability, with a higher score indicating maturity and calmness or self-control amidst difficulties. A lower score describes a person who is more easily distressed and influenced by feelings, and with a lower frustration tolerance.[14] The divers' higher scores reflect the demands of military diving which requires maturity and self-control, maybe more than for the general navy. A form of self-selection may have taken place, as only those who stay calm under difficulties would qualify and work as a clearance diver.

A high score on Factor F is indicative of an enthusiastic, happy-go-lucky person. It further points to a quick and alert person, without too many cares.[14] The higher score of the navy divers can then be expected, as such persons seem to adjust well in groups and to adverse environments.[13] Risk taking behaviour has also been correlated to high scores,[15] which may reflect the attitude of divers compared to those of the general navy personnel.

Factor I (tough-minded vs tender-minded) refers to emotional sensitivity, where a lower score describes a person who is tough and independent. A higher score describes a person who is more tender, sensitive and dependent.[14] A low score on this factor is favoured during the divers' selection process, and is further influenced by self selection during the arduous training where only the tough-minded complete the program. The low score for the divers could be expected, given their selection procedure and their training and work conditions.

The direction of the differences may indicate a good person-environment, or person-task fit, where individuals find themselves in that situation where they can successfully deal with the demand of the environment.

When compared to other divers not involved in the military, differences emerged on 6 traits, which is in contrast with a previous South African study which indicated that naval divers compare more closely with civilian divers than with general navy personnel on certain measures of anxiety and hostility.[16]

Factor E indicates dominance and poses obedience vs assertiveness. A person with a lower score is more obedient and easily influenced, while a person with a high score is more assertive and competitive.[14] The sport divers' higher scores on assertiveness may be an indication of their superior academic education. Their graduate status may tend to make them see themselves as more assertive than the navy divers, who were all junior NCOs at the time. The navy divers were also subject to military indoctrination, trained to follow orders, a form of conditioning not necessarily experienced by civilians. The lower (more obedient) scores of the non-diving navy group seem to support this explanation.

Factor G (super ego) poses a person who discards rules and chooses expedient solutions (lower score) against a person who is conscientious, rule-bound and persevering (higher score).[14] The higher scores of the naval divers may reflect their environment, the tightly regimented and regulated world of the military. Civilian divers do not necessarily live in such an environment, and are more free to choose expedient solutions.

A low score on factor M refers to a practical orientated person, who has his or her feet on the ground and is focussed on practical needs. A high score is indicative of an imaginative person, who is more caught up in ideas.[14] Navy divers live in a practical world, where they build or demolish or repair with whatever tools are at hand. The sport divers all had an academic background, which would prime them to be more comfortable with ideas and possibilities.

A high score on factor N is indicative of a shrewd, world-wise person, as opposed to a more naive, forthright person.[14] Why navy divers tend to be more world-wise is unclear. It can be that through their exposure in the navy they have seen more of life, but this remains speculation and needs to be further explored.

Factor Q_2 refers to group orientation, and low scores are typical of SAN divers.[13] Navy divers may be more group dependant, due to the nature of SAN diving which has a close focus on group work, interdependency for safety, etc. Sport divers may be less group dependant due to the nature of recreational diving, which can be done in buddy-pairs on their own, without any group affiliation. A positive group orientation is possibly also a trait of SA naval personnel in general, as studies with submariners have indicated,[17] reflecting the team-approach of SA Navy operations.

Factor Q_3 (self sentiment) poses individuals who are more careless, or less controlled, against individuals who are self-controlled, precise and even compulsive.[14] The demands of navy diving (adverse conditions, dangerous situations, technical challenges) may require a precision that is not necessary for the sport diver who mostly dives under pleasant conditions. Navy divers share this trait with submariners, who also require a high level of precision for the execution of their tasks.[17] Military indoctrination also encourage meticulous checking of equipment and imposes regimented diving procedures.

The differences with civilian divers may be a function of other factors not associated with their military/civilian backgrounds. As noted before, the sports divers come from a group with tertiary academic attainments, and a higher socioeconomic status. Ross found that student divers did not differ significantly from student non-divers on personality measures.[8] So the differences between navy divers and civilian divers may reflect a difference between young people of different educational backgrounds. More research would be needed to determine this.

Do navy divers constitute a unique group? Our findings suggest that they differ from non-diving naval personnel, which supports previous studies comparing divers with submariners, where there were differences on 2 traits using the same instrument.[13] It also gives support to other studies where navy divers differed from other navy non-divers on anxiety and hostility scales.[16] Some of the differences may be explained by selection, whether formal or self-selection, and some may reflect the diving environment. In comparison with civilian divers there are differences on 6 traits, some of which may again be explained by the demands of the military diving environment. In support of the findings, the groups were easy to compare, as they had the same size, without any significant differences in age, time in the navy, or time involved with diving. They were further all located in the same geographical area, although there was some gender inequality in the groups. However, it cannot be assumed that the samples are representative of their populations. The navy groups were recruited on the basis of availability, and were all taken from one naval base. In the same way the recreational divers were from only 2 clubs and some self-selection may have taken place when they responded to the invitation to participate in this research. The small sample size (28 per group) also cautions against easy generalisations. Trait personality is seen as fairly stable over time and is not expected to change too much due to environmental demands.[18] However, the 16PF profiles of this study could have been influenced by the norms of the different groups, and so reflect group culture as well as the personality traits associated with those groups. It is not clear to what extent the different gender mixes may have skewed the results. For example, women and men divers scored the same on the STAI,[7] and others have argued that "experienced female divers are similar in personality profile to other established divers".[19] It is possible that the women in the populations from which these groups were drawn from may have the same profiles as the men, but that cannot be assumed until further research is conducted.

These findings may suggest the value of using a person-task or person-environment model to view the results of studies like this one and the eventual potential for occupational placing. The military environment provides scope for a wide variety of personalities and only some are suitable for the tasks and demands of military diving. Occupational selection may be important for individuals within the military who express an interest in military diving, but some may not meet the person-task fit. This does not disqualify them from being good sailors and will allow the opportunity to direct them to other applications to meet their military aspirations. In the same way civilian divers applying for military diving may not necessarily meet the person-environment fit and may need to be directed elsewhere for developing their diving aspirations. However, the role of personality in predicting success in the South African diving context is only speculative and further research is needed to investigate this.

This study supports previous findings of SAN divers' personality traits and illuminated differences with non-diving naval personnel and differences with civilian sport divers. Due to the concerns regarding representivity, future research would benefit from larger numbers of participants which would increase the opportunities for generalisations. The use of more instruments may also give a more accurate measurement of group profiles and intergroup differences. Research comparing navy divers that succeed in training with those who do not and comparing divers who remain in the navy for longer service to those who leave after a short period, would help answer the question of what role personality plays in this person-task and person-environment fit.

In summary, navy divers are enthusiastic, adventurous, confident and group orientated. They display higher ego-strength, adventurousness and tough-mindedness than their non-diving counterparts in the navy. They were less assertive, displayed higher superego scores, practical orientation, shrewdness, group orientation and self-sentiment (precision) than civilian sport divers.

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COMMENTS OF A PEER REVIEWER

The implication from the introduction to this paper, is that this small cross-sectional study of navy divers, navy non-divers and non-navy divers, is adding to a relatively small medical literature on diver and sub-mariner selection, in the hope of using selection criteria for subsequent diving activities.

This is misleading for the following reasons.

1 There has already been a great deal of research undertaken on both psychometric assessments and occupational selection, during the post world-war 2 period, on both submariners and divers. It was mainly performed by the US navy and this is well reviewed in the references 1-3, as well as in the later investigations cited in references 4-15, together with their references.

In many of these reports, the investigations were conducted on large numbers of submarine and diving personnel, in a prospective manner – a much more informative research technique than a cross-sectional study, if one wishes to apply the results to selection.

2 One of these reports (ref 4), describes a prospective, psychometric and physiological analysis of 500 prospective navy divers, comparing the successes and failures and performing a discriminate function analysis upon them, with relative weightings to the various factors which positively or negatively are correlated with success

3 A great deal of information regarding various diving personality factors has been derived from both the psychiatric investigations into divers (of which only a few references were described in the above paper) and more especially of the many subsequent investigations into organic brain damage in divers, which utilized non-damaged diver controls. Reference 11 in the South African paper was thoroughly discounted in subsequent work (reference 12)

These papers have been surfacing in the diving literature since 1975, and have been the subject of at least three international symposia. They have been very informative regarding the personality characteristics of divers and also have clarified some of the problems in drawing conclusions, and which were not referred to in the above article.

Although some of the references are now difficult to obtain, most are still available from the navies that undertook the work and abstracts of the reports are still available in the more widespread medical literature.

It is possible that the author has limited himself to a very specific MEDLARS type search and thereby omitted many of the texts, published conference proceedings, and less recognized journals. Fortunately, much of the material is still obtainable from a comprehensive diving medical library. Alternatively, a personal approach to some of the experts or original workers in this field would have directed the author, and others, to these sources. To not have perused the literature because of this difficulty is hardly acceptable when the author uses references to his own unpublished research reports (his reference 16).

4 The statistical techniques employed are not ideal for their stated purpose, and their conclusions have to be questioned. As admitted in the article, the groups were not controlled for age, sex, education and IQ standards. The inadequacies of a small-number, cross-sectional study of different groups is appreciated by all, including the author. More importantly, the populations were selected differently.

The results could represent the effects of peer pressures to conform with the groups, i.e., they could reflect the mores and cultures of special communities (navy divers and recreational diving clubs), more than the characteristics needed for diving proficiency.

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LATE SEQUELAE OF CARBON MONOXIDE POISONING 2 CASE REPORTS

Robert Noll

Key Words

Carbon monoxide, hyperbaric oxygen, sequelae, treatment.

Introduction

Neuropsychiatric manifestations of acute carbon monoxide (CO) poisoning may include non-focal changes in mental state, seizures, amnesia, apraxia, agnosia, Parkinsonism, cortical blindness, incontinence and peripheral neuropathy. A lucid period of up to twenty one days may occur followed by the delayed sequelae of CO poisoning which may include aphasia, apathy, disorientation, psychosis, gait disturbances, faecal and urinary incontinence and bradykinesia. Cognitive and neurological deficits may also be present, as can personality changes with impulsiveness, violence, verbal aggressiveness and mood changes.[1]

This syndrome has a reported incidence of 3% to 40%,[2] with a set of risk factors having been identified within the group of affected patients.[3] The neuropsychological deficits associated with CO poisoning are highly variable despite exposure to similar levels of CO poisoning.[4] The white matter of the frontal lobe is involved but the pathological mechanism leading to demyelisation, petechiae, oedema and necrosis is poorly defined. Depressed cardiovascular function induced by CO, and a limited cerebral blood flow, may be major factors leading to neurologic cellular damage from CO poisoning.[1]

Case histories

The Hyperbaric Unit at Fremantle Hospital actively treats CO poisoning with about 30 cases per annum being referred from Perth and more remote regions. The unit recently treated two cases with apparent late sequelae with resulting clinical improvement.

CASE ONE

A 61 year old female patient, who attempted suicide by connecting the exhaust pipe of her car to the cabin, was found by her neighbour at about 0950 with the car engine still running. The Glasgow Coma Scale (GCS) at the site was reported to be 9/15. In the Emergency Department of a peripheral hospital the patient was noted to have deteriorated with hypotension (55/28 mm Hg). She had an oxygen saturation of 77% on air and an acidosis with a bicarbonate of 12.1 mmol/l (normal 22-32 mmol/l). Her ECG showed sinus tachycardia and carboxyhaemoglobin estimation revealed a level of 41.9% four hours after being removed from the vehicle. Transfer to Fremantle Hospital was accomplished with the patient intubated and ventilated.

In the Intensive Care Unit at Fremantle Hospital the patient was unrousable despite withholding all sedation. Initial treatment was performed using an 18 m for sixty minutes with a thirty five minute decompression (18:60:35) hyperbaric oxygen treatment (HBO_2T) table while the patient remained sedated and ventilated. Sedation was withdrawn overnight and extubation performed the following morning with improved and stable observations. The patient received two further daily treatments using the same treatment table. She was noted to have an improved mental state during and between visits to the chamber. Without sedation the patient responded to commands by eye opening only and was restless and disorientated during the second day. A fourth treatment using the RN 61 table was administered on day four after which it was noted that she was able to conduct a rational conversation and read printed material. The patient was handed over to the care of the medical team who discharged her seven days after admission. Appropriate psychiatric follow up had been arranged.

Eighteen days after her discharge the patient was readmitted with a marked deterioration in psychological, cognitive and neurological function after having been found at the side of the road in the driver's seat of her car and clothed only in a bath towel. Signs and symptoms included urinary and faecal incontinence, inability to perform routine activities of daily living, loss of short term memory, disorientation in time, place and person, ataxic gait, and inability to perform a Mini Mental State Examination (MMSE). Neuropsychological testing was difficult and attempted on two occasions with the latter revealing exceptional weakness in her Verbal Test Score and inability to negotiate Performance tests. Short and long term recall for verbal and non-verbal material was zero and the patient was unable to distinguish between her left and right hand.

The patient remained on a medical ward for four weeks at the end of which she was assessed to be suitable for nursing home care due to an inability to care for her self. A subsequent referral of the patient for hyperbaric treatment resulted in a series of 14 daily hyperbaric treatments using table 14:90:24 being administered with steady recovery almost on a daily basis. The patient regained urinary and faecal continence and independence in activities of daily living (ADLs). Post-treatment neuropsychological testing revealed an ability to cooperate with full scale IQ in the average range. Memory function assessment for verbal material was normal whilst non-verbal was moderately impaired.

The patient was discharged to live independently, although an assessment before hyperbaric treatment indicated permanent placement in hostel accommodation. At follow up interview the patient was functioning at a normal level living independently and requiring only the support of her local general practitioner.

CASE TWO

A 45 year old male had apparently been exposed to 30 minutes of car exhaust gas four days before assessment. Upon failing to follow through on his suicide attempt the patient had consumed beer and Prothiaden (dothiepin hydrochloride) without acute sequelae.

He presented to his General Practitioner with various symptoms and general malaise the day after the incident but was reassured there was nothing seriously wrong. No carboxyhaemoglobin estimation was performed at presentation. His condition deteriorated over several days following the poisoning with poor balance, headache, poor short-term memory and slow mentation noted by his wife. Initial assessment by the hyperbaric team four days later revealed a Sharpened Romberg of less than 5 seconds on three attempts, a Mini-Mental State Examination (MMSE) score of 17/30 and a GCS of 15/15.

Following a treatment using the 18:60:35 protocol four days after the poisoning the patient's MMSE improved to 23/30 and the Sharpened Romberg time was 40 seconds. The patient was given two further treatments with subsequent improvement arresting the decline in his condition. Treatment had to be curtailed for social reasons and the patient has not returned for review.

Discussion

The use of HBO_2T for carbon monoxide poisoning remains contentious with polarised views about its efficacy. A recent review of the evidence available suggests that a substantial study with adequate controls and patient numbers still needs to be completed.[5] These two cases had variable signs of delayed sequelae of carbon monoxide poisoning, however both responded to hyperbaric oxygen therapy. Clinical deterioration was reversed in both cases preventing nursing home placement in the female patient, who maintains her independence ten months after her treatment. Risk factors for neuropsychological sequelae include older age (50+ yrs), loss of consciousness, COHb > 25% and metabolic acidosis.[3]

Conclusion

In cases demonstrating neuropsychiatric sequelae due to CO poisoning it is worth considering hyperbaric oxygen therapy to assist in the recovery from a debilitating syndrome.

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THE WORLD AS IT IS

ABPM EXAM
WHAT IT'S ALL ABOUT

By Dr Caroline Fife with modifications by Dr James Vanderploeg

Undersea and Hyperbaric Medicine Board Certification

The American Board of Medical Specialities

Due to the comments we have received regarding the subspecialty examination, some further clarification about the exam is necessary. In the United States, a Chicago-based organisation called the American Board of Medical Specialties (ABMS) determines not only WHICH specialties will be recognised in the US, but what the rules will be for specialty and sub-specialty certification across the nation. For example, only physicians completing residencies accredited by the Accreditation Council for Graduate Medical Education (ACGME) are eligible to sit for specialty board examinations. (This excludes most osteopathic physicians unless they complete a traditional allopathic residency). All specialties recognised by the ABMS must abide by the rules set by the ABMS. The requirements of the American Board of Medical Specialties apply to all of its Member Boards who offer certification in the United States.

What is important about ABMS recognition?

While a US physician might train in a field not recognised by the ABMS, certifications which are not recognised in some way by the ABMS are usually of limited practical value in the US. The ABMS requirements for the recognition of a new medical specialty board are very stringent. The guidelines for the establishment of a new specialty or sub-specialty are such that no new specialties have been approved in the past 10 years. Furthermore, in order to maintain the designation of a "specialty" there have to be at least three residency programs in the US that are recognised by the ACGME. For these reasons (and because it is necessary to have a solid general medical background before concentrating on Undersea and Hyperbaric Medicine), it did not seem practical to seek approval of specialty certification in Undersea and Hyperbaric Medicine from the ABMS. However, a window of opportunity opened for Undersea and Hyperbaric Medicine to become a sub-specialty that would be recognised by the ABMS. Obviously, only physicians who already had an ABMS recognised specialty certification could get a sub-specialty certification. The question for the UHMS then became: Is it better to at least have an ABMS recognised ***Sub-specialty*** if the alternative is to continue trying to practice medicine outside of the mainstream? It seemed clear that the chance to be sub-specialty certified, despite all its limitations, was better than nothing.

It is important to understand that the UHMS has no authority to designate the rules by which either individual specialties or sub-specialties are recognised in the US. We could have chosen to do nothing, in which case no US physicians would have had the opportunity to become recognised as sub-specialists in Undersea and Hyperbaric Medicine. We could have waited several years hoping for a change in the philosophy of the ABMS and tried to gain specialty recognition. This might have allowed more US physicians to be included during the "grandfather" period, but it would still have excluded all international physicians, would have taken years to accomplish, and the odds of success were low.

The ABPM Exam

As you know, the American Board of Preventive Medicine (ABPM) agreed to sponsor the subspecialty application to the ABMS. Unfortunately, many international members viewed the UHMS supporting a sub-specialty process as a way of intentionally making international members "second class citizens". This same complaint was voiced by all the US doctors excluded from taking the examination because they are not currently board certified in an ABMS recognised specialty.

There is another very critical point: The "Practice Pathway" (whereby a physician is allowed to sit for an examination on the basis of having considerable experience but not formal fellowship training) is allowed for newly designated specialties and sub-specialties only until residencies and fellowships are created. After that, the opportunity to "grandfather" into the field by just taking the examination is lost, and the only way to be eligible to sit for an examination is to complete a recognised residency or fellowship.

These are rules determined by the ABMS, not by the UHMS. That is the reason that creating approved fellowships in Undersea and Hyperbaric Medicine is critical right now. In a few years, the ABMS will require that ONLY fellowship-trained physicians can take the sub-specialty examination.

A number of international members from several countries have indicated that being allowed to sit for an exam in the US could be of benefit in their own countries. As a result, at the recent UHMS meeting in San Antonio, we approached the ABPM to see if some sort of certification for international doctors would be possible. Although there is no precedent in the US for such a process, the ABPM was willing to discuss this possibility. However, it is not clear at this time what they will be allowed to do from the standpoint of the ABMS.

A formal letter has been sent from the UHMS to the ABPM requesting that the possibility of offering an examination to international physicians be discussed at their August meeting and see if there is a mechanism by which this could be accomplished. Whether the ABMS will allow the American Board of Preventive Medicine to proceed, what rules would apply if the test is offered, how much it would cost, and when and how often such an examination would be given are all unknown. Another interesting question is, if some sort of certification could be extended to international members, what will happen after five years if fellowships have not been created in those countries?

It is important for our members to understand that the UHMS has no control over the rules set by the ABMS. I deeply regret that the attempt to move undersea and hyperbaric medicine into the mainstream in the US was a source of frustration for our international colleagues. That was never the intention of the Society. It is our hope that we can find a way for this process to benefit international physicians and we will pursue this aggressively.

Reprinted, with minor editing, by kind permission of the Editor, from PRESSURE, the Newsletter of the Hyperbaric and Underwater Medical Society, 2001; 30 (5 September/October): 1 and 6.

Key Words
Qualifications.

THE AUSTRALIAN SITUATION

John Knight

Key Words
Qualifications, training.

Physicians in the United States now have a sub-speciality certification in Undersea and Hyperbaric Medicine available to physicians already Board Certified in some speciality.[1,2] However this new certificate is not available to physicians without American Board Certification in some speciality. This means that those doctors trained outside the USA cannot achieve the new sub-speciality certification.

The situation is quite different in Australia where the first non-military certification in Diving or Hyperbaric Medicine was established in 1974 when the South Pacific Underwater Medicine Society (SPUMS) "grandfathered" a small number of Australian, New Zealand and overseas doctors practising diving or hyperbaric medicine as the first holders of the Diploma of Diving and Hyperbaric Medicine (DDHM). The first Diplomas to be earned by examination were awarded in 1975 to Drs Chris Acott, John Dawson and John Knight.[3] Being a Diploma, requiring passing two diving medicine and one hyperbaric medicine course, six months full-time or equivalent part-time experience and a thesis, none of the Universities in New South Wales was interested in sponsoring it. At that time University diplomas were being replaced by degrees.

However possession of the SPUMS Diploma was, and still is, clear evidence of a reasonable understanding and practical experience in Diving and Hyperbaric Medicine

(DHM). With the establishment of more Hyperbaric Units across Australasia there was a need for a higher qualification denoting education and experience suitable for appointment as Director of such a unit.

Approaches to various licensing bodies were unproductive. Basically their line was that higher qualifications had to involve an academic body, one of the various colleges of specialists, which had to oversee the training. But what College was suitable to oversee training in DHM when DHM got no mention in undergraduate medical courses and expertise was limited to a small number of SPUMS members? The answer was “None”.

So the higher qualification languished in the Society’s in-tray for years until Dr Bob Wong, Director of the Department of Diving and Hyperbaric Medicine at Fremantle Hospital in Western Australia, had a brainwave. The Australian and New Zealand College of Anaesthetists (ANZCA) has occasionally established Special Interest Groups (SIGs) for interested anaesthetists. The first SIG was for those interested in intensive care. It went on to develop a syllabus, a certificate and eventually became the Faculty of Intensive Care ANZCA. Bob’s idea was to approach the ANZCA to form a Diving and Hyperbaric Medicine SIG. One of the requirements for all SIGs is that everyone, not just anaesthetists, who is interested in the subject can join. Intensive Care in Australia was provided by interested specialist physicians in some hospitals and by interested anaesthetists in others so two specialist colleges were involved and their members, if adequately trained, can become a Fellow of the Faculty of Intensive Care.

After a bit of negotiating with the ANZCA Board Bob was able to get agreement from the College that a DHM SIG executive be formed and that both SPUMS and the Australian and New Zealand Hyperbaric Medicine Group, which is an independent sub-committee of SPUMS (I am not sure that makes sense but there it is) consisting of the Directors of the Australasian Hyperbaric Units and any medico working in those units, were allowed seats on the new Executive. Dr Wong recruited an anaesthetist with training in DHM from each State in Australia and from the Northern Territory and New Zealand to join the other two representatives. I was the SPUMS representative at first and now represent Victoria. The first problem facing the SIG was membership and the College was very co-operative in allowing all those with an interest in DHM to be considered for membership of the SIG. Although most of the Australasian hyperbaric units are run by anaesthetists some are run by emergency medicine specialists and some by those with long training and much experience in DHM.

So the DHM SIG Executive, chaired by Dr Wong, needed to set a standard (syllabus and examination) and a time frame for the desired certificate. The DHM Executive agreed that the SPUMS DDHM was to be a mandatory part of training for the proposed ANZCA certificate. Dr Michael Bennett, of the Prince of Wales Hospital in Sydney and Dr Margaret Walker, of the Royal Hobart Hospital in Tasmania, spent many hours in producing the training syllabus. The matter of a DHM Certificate was raised with the ANZCA Executive in June 2000.

Besides the proposed certificate, evidence of training, the DHM SIG Executive have been working on standards of practice and accreditation of hyperbaric units. Over recent years a number of small hyperbaric facilities outside hospitals have been set up and the SIG executive has felt that if hospitals have to be accredited so should hyperbaric units.

As this is written decisions about who will be “grandfathered” and whether they should sit an exam, for which there is considerable support, have not yet been taken by the DHM SIG Executive. Some members of the Exutive feel that “grandfathering” should only apply to a few senior DHM practioners and then all candidates for the Certificate should pass an examination. The final details of the Certificate will be determined by the ANZCA Certificates Committee, which comprises a Chairman, who is an ANZCA Councillor, the Chairman of Examinations or his/her nominee, a Councillor, the Director of Professional Affairs, a Fellow (R Wong) and two co-opted nominees from the particular area of expertise. This Committee should meet in the coming months of 2002.

The DHM SIG Executive looks forward to the College’s adoption of its suggestions which will lead to a more uniform standard of training and better clinical practice in all hyperbaric facilities. The Executive also hopes that, in time, the Certificate will be accepted as a registerable qualification so outlining a career path for DHM practitioners.

For the information of members an edited version of the DHM SIG’s Training Program and Objectives of Training in DHM appear on the following pages.

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DHM SIG TRAINING PROGRAM

Summary

We propose that training for the suggested ANZCA "Certificate of Diving and Hyperbaric Medicine" be conducted as outlined in this document. There will be three main elements of this training: course work, research and practical experience. It is further proposed that attainment of the present Diploma in Diving and Hyperbaric Medicine, as conducted under the auspices of the South Pacific Underwater Medicine Society (SPUMS), be a pre-requisite for certification.

The SPUMS Diploma is the only local qualification relevant to the field and is well established. The SPUMS organisation maintains a sophisticated system of research evaluation and review under the auspices of an Education Officer elected by the members, and a reviewed, publication standard project is a requirement for this diploma. We feel that duplication of such research projects for certification by the College would be unnecessary and wasteful of limited resources.

Formal course requirements

In order to reflect the two distinct sub-disciplines of which Diving and Hyperbaric Medicine is composed, we propose that two periods of formal instruction be successfully undertaken to satisfy the requirements of the certification. Each of these would be of a minimum duration of two weeks. One course would be primarily Diving Medicine orientated (eg Royal Adelaide Hospital, HMAS Penguin), while the other would be primarily Hyperbaric Medicine orientated (eg the SIG/ANZHMG Course). Courses would be of the standard required by the SPUMS Diploma as currently constituted.

One course would be undertaken early in training, as required by the present Diploma, while the other could be completed at any time up to the end of training. This would give a total of four weeks formal, didactic training from a wide range of specialists in the field.

Practical experience

The present Diploma requires six months of formal, full-time, experience working in a hyperbaric facility. We propose a further one year full time equivalent (FTE) of training in a facility accredited by the ANZCA SIG for this purpose. This results in a total requirement for 18 months of FTE training in Diving and Hyperbaric Medicine. This requirement may be satisfied by a longer period undertaken at less than 1 FTE, such that the 18 month FTE is achieved. We anticipate this will be the usual process, as it is unlikely that many will chose to work as a trainee full-time. A formal process of accreditation for training will need to be implemented by the College.

In addition to a time commitment, we propose that a **workbook** be kept by each trainee, documenting a minimum

TABLE 1

WORKBOOK ELEMENTS. *INDICATES ITEMS THAT MAY BE SIMULATED.

Broad Category	Detailed Experience	Minimum Required
Patient Assessment	Assessment of routine patient for therapy	30 Patients
	Assessment of emergency patient	15 Patients
	Transcutaneous oxygen mapping	5 Patients
	Tympanometry	20 Patients
Hyperbaric Therapy	Supervision of routine treatment	50 Chamber cycles
	Supervision of emergency treatment	15 Chamber cycles
	Supervision of emergency treatment for necrotising infection	4 Treatments
	In-chamber attendance	20 Chamber cycles
	Planning of dressing regime for chronic wound management	10 Patients
Diving Medicine	Assessment of fitness for recreational diving (novice) or hyperbaric attendance	10 Candidates
	Supervision of diver retrieval and assessment for treatment	10 Patients
	Supervision of initial diver recompression	10 Recompressions
	Counselling following treatment for DCI/CAGE	10 Patients
Complications	Assessment and treatment of barotrauma	10 Patients
	Assessment of hyperbaric myopia	10 Patients
	Treatment of hyperoxic seizure*	1 Patient
	Emergency chamber access for resuscitation*	1 Patient

number of essential practical tasks be completed. Each entry would require counter-signature by a qualified supervisor. Our suggested range of experience and repetitions is shown in Table 1.

Assessment

We propose a three-element assessment process for certification. **Element one** would be the attainment of the SPUMS Diploma of Diving and Hyperbaric Medicine and this will cover a research component and formal training component. **Element two** would be satisfactory completion of the workbook. **Element three** would be successful negotiation of an examination to be sat at or near the end of the training period. This examination would cover knowledge in the areas identified in the curriculum below.

Proposed Curriculum

History of Diving and Hyperbaric Medicine
- Diving history
- Recompression history
- Air and oxygen treatment
- Current accepted indications
- Non-accepted indications

Practical Aspects of Hyperbaric Therapy
- Chamber types
- Operational safety
- Emergency procedures
- Oxygen delivery systems
- Environmental systems

Physics of Hyperbaric Medicine
- Gas laws
- Pressure conversion
- Adiabatic temperature variation

Mechanisms of action in Hyperbaric Medicine
- Compression of bubbles
- Hyperoxia
- Immune system modulation
- Enhancement of healing

Treatment tables
- Historical review
- Oxygen as a drug
- Rational choice

Hyperbaric Safety and Emergency Procedures
- Operational, fire and electrical safety
- Safety codes and standards
- Emergency procedures

Physical Aspects of Diving
- Diving physics
- Diving equipment
- Mixed-gas diving
- Breath-hold diving

Diving Physiology
- Compression of solids and liquids
- Respiratory changes on immersion
- Cardiovascular response to immersion

Hyperbaric Medicine Accepted Indications
- UHMS, EUBS and Australian Accepted Indications
- Decompression illness
- Cerebral arterial gas embolism
- Carbon Monoxide poisoning
- Acute necrotizing infections
- Acute traumatic ischaemias
- Problem wounds
- Osteoradionecrosis
- Soft tissue radionecrosis
- Compromised flaps and grafts
- Refractory osteomyelitis
- Exceptional blood loss anaemias
- Thermal burns
- Intra-cranial abcess
- Miscellaneous indications

Diving Injuries
- Decompression Illness
- Barotrauma
- Salt water aspiration
- Decompression theory
- Rationale of dive tables
- Retrieval of the injured diver

Diving-related disorders
- Inert gas narcosis
- High pressure nervous syndrome
- Aseptic necrosis of bone
- Ear and sinus problems
- Neurological consequences

Other Immersion Disorders
- Hypothermia
- Near Drowning
- Pulmonary disorders
- Cardiovascular disorders

Cerebral Arterial Gas Embolism
- Diving related
- Iatrogenic
- Management

Assessment of Fitness to Dive
- Professional
- Recreational
- Attendant staff

Marine Envenomation

- Common dangerous sea creatures
- Management
- Sources of expert advice

Human Performance and Diving

- Human performance underwater
- Women in diving
- Diving by the elderly and the young

Diving supervision

- Medical supervision of diving operations
- Principles of saturation diving
- Common medical problems in saturation diving

Toxicity of Respired Gases

- Oxygen toxicity
- Carbon Dioxide toxicity
- Carbon Monoxide
- Cyanide, H2S

Problem Wounds

- Mechanisms of wound healing
- Assessment of wounds
- Treatment of problem wounds
- Multidisciplinary wound clinics and the role of HBO

Radiation Tissue Damage

- Pathophysiology of radionecrosis
- Prevention and treatment of osteoradionecrosis
- Soft-tissue radionecrosis

Ischaemia-reperfusion Injury

- Pathology of I-R Injury
- Treatment of I-R Injury
- Role of HBO

Complications and contra-indications in Hyperbaric Medicine

- Risk factors
- Absolute contra-indications
- Relative contra-indications
- Management of complications

Transcutaneous Oxygen Tensions

- Physiology
- Patient selection for therapy
- Practical aspects of mapping
- Role as endpoint

Hyperbaric and Intensive Care

- Patient selection and preparation
- Mechanical ventilation under pressure
- Management of lines and infusions

Ethics of hyperbaric practice

- Approach to "off list" indications
- Research methods
- International register of unusual cases

Patient management

- Admission and discharge criteria
- Infection control
- Diabetic control under pressure
- Planning a treatment course

Record Keeping

- Database issues
- Transcutaneous oxygen mapping
- Medical photography
- Quality assurance

Standards

- Standards relating to facility
- Standards relating to staffing
- Standards for 'Fitness to dive'
- Local and international

Evidence Based Medicine and Hyperbarics

- Concepts
- Resources available
- Using the internet

Administrative Issues

- Reimbursement
- Professional societies

Practical Skills

- Transcutaneous oxygen measurement
- Chamber operation
- In-chamber attendance
- Assessment of fitness to dive
- In-water expired air resuscitation and diving safety
- Ancillary equipment operation

Competencies

Successful completion of the certification process will require the candidate to demonstrate:

1 A satisfactory level of understanding of the hyperbaric physical environment
2 An ability to develop a rational approach to the assessment, diagnosis, selection, treatment and outcome assessment of patients presenting for consideration of hyperbaric therapy
3 An ability to diagnose and manage the complications of hyperbaric therapy
4 Practical ability to perform investigations and treatment relevant to hyperbaric patients, including insertion of chest drains, performance and interpretation of transcutaneous oxygen mapping studies and conduct of assessments of fitness to dive
5 A satisfactory level of understanding of the diving environment and the safe conduct of underwater diving

6 Physical fitness to enter the hyperbaric environment
7 An understanding of the administrative and quality management commitments required for the safe and effective conduct of hyperbaric therapy
8 An understanding of the research process as it relates to diving and hyperbaric medicine

The next steps

In order to move the certification process along, the SIG will be required to act on several fronts with some speed. It is our opinion that the following are of high priority:

Grandfathering.

We propose that the individuals currently acting in the capacity of "hyperbaric and diving specialists" be granted the certification, as soon as such can be arranged, in order to generate an enthusiastic group of potential trainers and examiners. We do not believe this would be inappropriate given the small numbers involved. This would include individuals with the DipDHM working as medical directors of suitable facilities, regardless of their Specialist Fellowship status, as well as those working under Anaesthesia, Emergency Medicine or other primary specialist qualifications. This *does not* imply that in the future the certification should be open to those without such specialist qualifications, but *does* reflect the state of the field prior to the emergence of the SIG.

The criteria currently accepted by the Executives of the SIG for "grandfathering" are those who:
a Are in hyperbaric practice at least 2 sessions a week,
b have accumulated at least 18 months full-time (or equivalent part-time) experience in the field of diving and hyperbaric medicine in an acceptable Hyperbaric Unit (acceptable to the Executives of the SIG),
c hold a Fellowship such as FANZCA, FACEM, FFOM, or MD or PhD in a relevant area,
d hold the Diploma of Diving & Hyperbaric Medicine of SPUMS,
e have adequate airway skills,
f are involved in training of medical officers, nurses and technicians,
g are involved in continuing medical education (CME), quality assurance (QA), teaching and research activities

Accreditation

Plans should be made as soon as possible to accredit hyperbaric facilities for training purposes. The SIG needs to discuss urgently the appropriate criteria for such accreditation, and in particular if accreditation will be for a standard or variable time across all such facilities. The initial accreditation, at least, may be effected without on-site visits if a sufficiently clear document could be generated outlining appropriate requirements.

Agreement with SPUMS

The South Pacific Underwater Medicine Society is an important player in the training and education of DHM Specialists. They administer the only formal qualification in the field and publish the only local journal relevant. While the SIG derives distinct political and academic advantage from the formal relationship with a specialist college, it would be unfortunate if two separate systems of training were to develop in this small area. The SIG should pursue, as a matter of urgency, an active role in ensuring that SPUMS is willing to allow the DipDHM to form an integral part of the certification process, rather than an alternative to this process. Some form of "escape clause" may be required should SPUMS alter the requirements for the Diploma such that it was no longer a suitable interim goal.

PRECIS OF THE OBJECTIVES OF TRAINING IN DIVING AND HYPERBARIC MEDICINE

Seven Sections

Patient Assessment, Hyperbaric Oxygen Therapy, Diving Medicine, Wound Management, Complications, Indications and Contraindications, Research and Development.

Patient assessment

Initial assessment, Previous history, Clinical examination and investigation, Effects of HBO_2T.

Hyperbaric Oxygen Therapy

Physiological effects of HBO_2T, Equipment for HBO_2T, Hyperbaric Therapy for the critically ill patient.

Diving Medicine

Diving medical assessments, Diving Accidents, Commercial Diving, Marine envenomation, Other immersion disorders, Diving-related disorders.

Wound management

Complications of HBO_2T

Barotrauma, Hyperbaric Myopia, Oxygen toxicity.

Indications and contraindications for HBO_2T

Accepted indications, Contraindications to HBO_2T.

Research and development

Research , Administration and Quality Assurance.

Key Words

Hyperbaric oxygen, medical conditions and problems, qualifications, training.

SPUMS NOTICES, COURSES AND MEETINGS

SOUTH PACIFIC UNDERWATER MEDICINE SOCIETY

DIPLOMA OF DIVING AND HYPERBARIC MEDICINE

Requirements for candidates

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

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

2 The candidate must supply evidence of satisfactory completion of examined courses in both Basic and Advanced Course in Diving and Hyperbaric Medicine at an approved institution.

3 The candidate must have completed the equivalent (as determined by the Education Officer) of at least six months full time training in an approved Hyperbaric Medicine Unit.

4 The candidate must submit a written research proposal in a standard format for approval by the Education Officer before commencing their research project.

5 The candidate must produce, to the satisfaction of the Education Officer, a written report on the approved research project, in the form of a scientific paper suitable for publication.

Additional information

The candidate must contact the Education Officer to advise of their intended candidacy, seek approval of their courses in Diving and Hyperbaric Medicine and training time in the intended Hyperbaric Medicine Unit, discuss the proposed subject matter of their research proposed, and obtain instructions before submitting any written material or commencing a research project.

All research reports must clearly test a hypothesis. Preference will be given to reports of original basic or clinical research. Case series reports may be acceptable if thoroughly documented, subject to quantitative analysis, and the subject is extensively researched and discussed in detail. Reports of a single case are insufficient. Review articles may be acceptable if the world literature is thoroughly analysed and discussed, and the subject has not recently been similarly reviewed. Previously published material will not be considered.

It is expected that all research will be conducted in accordance with the "Joint NH&MRC/AVCC statement and guidelines on research practice" (available at http://www.health.gov.au/nhmrc/research/nhmrcavc.htm). All research involving humans or animals must be accompanied by documentary evidence of approval by an appropriate research ethics committee. It is expected that research project and the written report will be primarily the work of the candidate.

The Education Officer reserves the right to modify any of these requirements from time to time.

The Education Officer's address is Dr David Doolette, Department of Anaesthesia and Intensive Care, The University of Adelaide, Adelaide, South Australia 5005. Telephone + 61-(0)8-8303-6382. Fax +61-(0)8-8303-3909. E-mail <David.Doolette@adelaide.edu.au>.

Key Words
Qualifications.

APOLOGIES

The South Pacific Underwater Medicine Society Journal apologies to Dr Carl Edmonds for printing Tables 1 and 2 in Dr Robert Wong's paper *Abalone diving in Western Australia: diving practices*, pages 131-135 in the September 2001 issue, without any acknowledgment that they were taken from Dr Edmond's book *The Abalone Diver*.

The South Pacific Underwater Medicine Society Journal also apologies to Drs Robert Wong and David Wright for an editorial error which added Dr Wright's name as an author to Dr Wong's paper *Aseptic bone necrosis as a diagnostic puzzle*, pages 135-138 in the September 2001 issue.

MINUTES OF THE SPUMS EXECUTIVE COMMITTEE MEETING PRINCE OF WALES HOSPITAL, SYDNEY HELD ON 2001/11/11

Opened 0930

Present

Drs R Walker (President), G Williams (Immediate Past-President), C Meehan (Secretary), B Trytko (Treasurer), D Doolette (Education Officer), D Walker, S Mitchell (Committee Members) and M Bennett (ANZHMG Representative).

Apologies

Drs J Knight (Editor), C Acott (Committee Members), D Smart (ANZHMG Chairperson)

1 Minutes of the previous meeting (2001/5/28)

Moved that the minutes be accepted as a true record. Proposed Dr S Mitchell, seconded Dr G Williams, carried.

2 Matters arising from the minutes

2.1 Dr Williams circulated the convener's manual. This manual was written by Dr Acott and updated by Dr Williams.

2.2 Dr Meehan presented an update of administration issues supplied by S Goble.

2.3 The SPUMS equipment should be covered by the individual committee member's home insurance policy.

2.4 Update by Education Officer, Dr D Doolette on pending diplomas, the future of SPUMS diploma, and possible affiliation with a tertiary body. Committee is aware that Professor D Gorman is developing a diving and hyperbaric medicine course in New Zealand. Dr R Walker, Dr M Bennett, and Dr D Doolette will discuss this further with Dr Gorman. A document from Dr M Davis outlining the responsibilities of the education officer and the academic board of SPUMS was discussed, as well as the credentialing of courses and hyperbaric units for clinical experience for purposes of the SPUMS diploma. There will be further discussions on the above issues with the SIG.

2.5 Update on the Journal index.

2.6 Update on SPUMS involvement with an UHMS meeting proposed in Sydney, May 24-29, 2004. There is a verbal go ahead only at the moment. International Conference and Events (ICE), in Sydney will be the conference organisers. The SPUMS Committee has agreed to sponsor the Kronhein speaker. It is proposed to hold the SPUMS ASM immediately following the UHMS. Heron Island was suggested as a suitable venue.

2.7 Update on statement to be published outlining the minimum age for diving and clarifying the SPUMS recommendations. The recommended medical opinion of SPUMS will be reinforced and published in *Australian Medicine*. Dr R Walker will do this.

2.8 Update on NZ Chapter. The Chapter needs to be formally closed, the appropriate constitutional changes made and put to the next ASM.

2.9 The outgoing chairperson, Dr Mike Bennett, gave an update from ANZHMG. The new chairperson is Dr David Smart, and the Secretary is Dr David Wilkinson. Matters covered were accreditation of units, continued involvement with HTNA activities and Medicare services committee review. The ANZHMG course is planned for April 8-19 in Melbourne, and will be run by the Alfred on behalf of the Diving and Hyperbaric Medicine SIG and ANZHMG.

2.10 Dr Knight finishes as Editor at 2002 AGM, a successor is needed. Dr R Walker will write to Dr Mike Davis to get a proposed starting time. There needs to be a formal contract between SPUMS and the Editor. Dr David Doolette will find a contract.

2.11 SPUMS oxygen kit will be revised and bought up to current standards and modernised.

3 Annual Scientific Meetings

3.1 2001 ASM, Madang, PNG, profit and loss presented. There was some profit, as one of the invited guest speakers did not attend. In view of this $5,000 will be donated to the local hospital.

3.2 2002 ASM, Iririki Island, Vanuatu. Dr Robyn Walker has completed a site visit. The guest speaker is Dr Trish Batchelor. She is the National Medical Director of **The Travel Doctor** and a guest lecturer at the University of Otago.

3.3 2003 ASM, Palau. Convener will be Dr C Meehan.

3.4 2004 ASM, Heron Island. Convener will be Dr G Williams.

4 Treasurer's Report

The previous Treasurer is perceived as still owing money. Dr Trytko is to pursue this. The CPI increase has been added to the wage of the Administrator and honorarium of the Editor and back dated to the Madang AGM.

5 Correspondence

5.1 Letter of complaint from Carl Edmonds. The SPUMS journal will print a formal apology.

5.2 E-mail V Cummins.

6 Other Business

6.1 Thoracic Society meeting and SPUMS and asthma and diving. Dr C Meehan is to write to the Thoracic Society and suggest that a working party be formed with representatives from both Societies to come up with a discussion document that both societies will look at. Drs S Mitchell, M Bennett, C Meehan, P Thomas, D Yates and G Simpson have all expressed an interest in being involved.

6.2 Dr J Knight's library. The Committee gratefully accepted Dr J Knight's offer of his diving medical library. The library will be housed at the Prince of Wales Hospital Hyperbaric Unit. Copies of the SPUMS Journal will be housed there as well.

6.3 Dr G Williams raised the First aid management diving incidents. Dr Bennett will send the NSW ambulance proforma to Dr Williams.

6.4 CME Points for SPUMS Meetings were discussed.

6.5 Audio Recording of ASMs was raised by Dr G Williams. There is need for some back up equipment.

6.6 Dr D Walker gave an update on Project Proteus along with a request for expressions of interest.

Closed 1600

THR 2002 ANNUAL SCIENTIFIC MEETING OF SPUMS

to be held at

Iririki Island Resort, Port Vila Vanuatu

Dates

Friday May 17th to Friday May 24th
(barring airline scheduling changes)

Themes

Diving and travelling in remote localities
Morbidity and mortality associated with diving equipment

The Guest speaker is

Dr Trish Batchelor

National Medical Director
of the **The Travel Doctor**
which is still in the Melbourne Telephone Directory as Travellers' Medical and Vaccination Centre

Members wishing to present papers should contact
CMDR Robyn Walker
Deputy Fleet Medical Officer,
Maritime Headquarters
1 Wylde St, Potts Point,
New South Wales 2011, Australia
Phone + 61-02-9359-4563.
Fax + 61-02-9359-4554
E-mail <Robyn.Walker@defence.gov.au>

The Official Travel Agent is

Allways Dive Expeditions
168 High Street
Ashburton, Victoria 3147, Australia
Tel + 61-(0)3-9885-8863
Toll Free 1800-338-239
Fax + 61-(0)3-9885-1164
E-mail <allwaysdive@atlasmail.com>

NOTICE TO AUTHORS

With the recent introduction of new copyright laws and the development of Mexitext, a medical electronic database, which is available on line by subscription, there is a need to have formal standard conditions for publication which cover printed and web accessible electronic publication.

In future all authors will have to agree to these conditions in writing before their papers can be accepted by the South Pacific Underwater Medicine Society Journal. The conditions cover copyright and royalties and include the statement that the author "will always be acknowledged as the copyright owner of the article".

Although this means more paperwork for the Editor the new agreement has advantages for our authors, giving certainty about their copyright position.

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As a contributor to the South Pacific Underwater Medicine Society Journal, I acknowledge and accept the following terms and conditions of publication:

1 I grant the South Pacific Underwater Medicine Society Journal a non-exclusive licence to publish my article, currently entitled [name of article] in printed form in the South Pacific Underwater Medicine Society Journal and in other media, including electronic form.

2 I grant the South Pacific Underwater Medicine Society Journal the right to sub-licence third parties to exercise all or any of these rights on my behalf.

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4 The South Pacific Underwater Medicine Society Journal agrees that in publishing my article and exercising this non-exclusive publishing sub-licence, I will always be acknowledged as the copyright owner of the article.

Key Words
Copyright.

NOW AVAILABLE

The South Pacific Underwater Medicine Society has produced a CD, readable by at least Windows and Macintosh computers, containing every issue of the Society's Newsletter and Journals as Adobe .pdf documents, from the first issue in May 1971 until and including December 2000. All that is needed to read and print these documents is Adobe Acrobat Reader (version 3 or later) which can be downloaded free from the Adobe web site.

None genuine without this label

The CD also contains the index for the South Pacific Underwater Medicine Society Journal. This runs from 1971 (Volume 1) to December 2000 (Volume 30 No. 4).

The index is supplied as a downloadable tab-separated document which can be entered into the reader's database. It is supplied in RTF (rich text format) and as Windows 97 DOC and TXT for Windows. Macintosh formats are RTF and Word for Mac 5.1.

The CD is available for $Aust 25 (including GST or overseas mailing charge) from either

The Editor of the South Pacific Underwater Medicine Society Journal or
The Administrator of SPUMS

The address of both is
C/o ANZ College of Anaesthetists
630 St Kilda Road
Melbourne, Victoria 3004
Australia

SPUMS PRIZE

FOR THE BEST PAPER PRESENTED AT THE HYPERBARIC TECHNICIANS AND NURSES ASSOCIATION SCIENTIFIC MEETING 2001.

The South Pacific Underwater Medicine Society wishes to congratulate Corry Van Der Broek, of the Royal Hobart Hospital Hyperbaric and Diving Medicine Unit, for his paper, *Are Our Nurses Safe? A Risk Assessment of Treatment Profiles Using Doppler*, which won the SPUMS Prize for the best paper presented at the Hyperbaric Technicians and Nurses Association Scientific Meeting 2001.

ANNUAL GENERAL MEETING 2002
NOTICE OF MOTION FOR CONSTITUTIONAL CHANGE

As the New Zealand Chapter of the South Pacific Underwater Medicine Society is no longer active the Committee will move the motion printed below at the Annual General Meeting.

Motion

Proposed that the Statement of Purposes and Rules be amended by altering Rules 22 (a) and 22 (c).

Rule 22 (a) be altered by deleting the words *a representative appointed by the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated.*

Rule 22 (c) be altered by deleting the words *the representative appointed by the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated* in the first sentence and by deleting the words *and the others by the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated and* in the second sentence. Also the word *respectively* at the end of the second sentence. The deleted words *and the others by the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated and* to be replaced by *the other by.*

The present Rule 22 (a) reads

The Committee shall consist of a President, Immediate Past President, a Secretary, a Treasurer, Public Officer, the Editor of the Journal, an Education Officer, a representative appointed by the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated, the Chairman of the Australian and New Zealand Hyperbaric Medicine Group and three other members of the Association entitled to vote.

The present Rule 22 (c) reads

(c) The Editor, the Public Officer, the representative of the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated and the Chairman of the Australian and New Zealand Hyperbaric Medicine Group shall be appointed to their positions. The first two by the Committee, the others by the New Zealand Chapter of the South Pacific Underwater Medicine Society Incorporated and the Australian and New Zealand Hyperbaric Medicine Group respectively.

The new Rule 22 (a) will read

The Committee shall consist of a President, Immediate Past President, a Secretary, a Treasurer, Public Officer, the Editor of the Journal, an Education Officer, the Chairman of the Australian and New Zealand Hyperbaric Medicine Group and three other members of the Association entitled to vote.

The new Rule 22 (c) will read

The Editor, the Public Officer, the Chairman of the Australian and New Zealand Hyperbaric Medicine Group shall be appointed to their positions. The first two by the Committee, the other by the Australian and New Zealand Hyperbaric Medicine Group.

Key Words

Constitutional amendments

DIVING AND HYPERBARIC MEDICINE INTRODUCTORY COURSE

The Alfred Hospital
Melbourne
April 8th to April 19th 2002

Applications are invited for a two week, full time course aimed at doctors interested in the fields of therapeutic diving and hyperbaric medicine. This includes referring clinicians who wish to gain more knowledge about the field as well as doctors who are involved or may become involved in the operation and supervision of hyperbaric medicine facilities.

The course is jointly presented by
The Australian and New Zealand College of Anaesthetists Special Interest Group in Diving and Hyperbaric Medicine
and
The Australian and New Zealand Hyperbaric Medicine Group

The course has been offered at Prince of Wales Hospital, Sydney in 2000 and 2001. The course faculty includes speakers from most of Australia's major hyperbaric units. Significant practical work is included and attendees are strongly encouraged to experience pressurisation in The Alfred's state of the art rectangular, walk-in chambers. A comprehensive set of course notes will be provided.

Topics to be covered include

Physics and physiology underlying Diving and Hyperbaric Medicine
Decompression illness, gas embolism, gas toxicity
Hyperbaric oxygen mechanisms
Hyperbaric chamber operations and safety
Ventilation and intensive care management under pressure
Application of HBO in "approved indications" such as:
- radiation tissue damage, diabetic micro-vascular disease, necrotising infections, crush injury, compartment syndrome and acute ischaemias
- Evidence based medicine and information resources
- Review of common "off-list" uses promoted by some alternative, paramedical and sports clinics

Course Fee $1,650 (including GST)

Credits

Fulfils course requirements for SPUMS Diploma and the forthcoming ANZCA SIG Certificate. Accredited, via UHMS, for 70 US CME points.

Enquiries to

Ms Elmarie Celestial or Dr Ian Millar
The Alfred Hyperbaric Service
Phone (03) 9276 2269Fax (03) 9276 3052
Email <hyperbaric@alfred.org.au>

ROYAL ADELAIDE HOSPITAL HYPERBARIC MEDICINE COURSE

Medical Officers Course

July 2002

Basic	8/7/02	to	12/7/02
Advanced	15/7/02	to	19/7/02

October/November 2002

Basic	21/10/02	to	25/10/02
Advanced	28/10/02	to	1/11/02

Cost

Basic Diving Medicine Course	**$825.00**
Advanced	**$825.00**

Diving Medical Technicians Course

Cost of three unit course$Aust 1,375.00

July 2002

Unit I	24/6/02	to	28/6/02
Unit II	1/7/02	to	5/7/02
Unit III	8/7/02	to	12/7/02

October 2002

Unit I	7/10/02	to	11/10/02
Unit II	14/10/02	to	18/10/02
Unit III	21/10/02	to	25/10/02

Diver Medical Technician Refresher Courses

July 2001	1/7/02	to	5/7/02
October 2001	14/10/02	to	18/10/02

Cost **$Aust 550**

For further information or to enrol contact
The Director,
Hyperbaric Medicine Unit
Royal Adelaide Hospital,
North Terrace
South Australia 5000.
Telephone Australia (08)-8222-5116
Overseas +61-8-8222-5116
Fax Australia (08)-8232-4207
Overseas +61-8-8232-4207

XIV INTERNATIONAL CONGRESS ON HYPERBARIC MEDICINE

October 2nd - 5th 2002
St Francis Hotel
Union Square
San Francisco, California, USA

CALL FOR ABSTRACTS

Abstracts of communication are invited from individuals who are involved in hyperbaric medicine. Abstracts submitted for the 2002 ICHM Meeting should not have been published nor presented before international meetings prior to this meeting. Deadline for abstract submittal is 2002/4/1. Specific instructions for preparing abstracts can be found at the ICHM web page <www.ichm.net>.

E-mail transmission of Abstract Submission Form and abstract should be sent to <ichm@milx.net>. On subject line type: ICHM Abstract. Persons who do not have e-mail may send a camera-ready hard copy and diskette to:

ICHM Meeting Secretariat
International ATMO
414 Navarro, Suite 502
San Antonio, Texas 78205

Both oral and poster sessions are available for presentations, which will be made in English.

The first author listed will be the presenting author. Priority will be given to those abstracts where the presenting author has registered before 2002/4/1.

In all cases the presenting author must be registered by the close of registration, which is 2002/8/1. Presenting authors will be notified of either acceptance or rejection not later than 2002/8/15.

Accepted abstracts of those who are registered at the meeting will be published in the usual manner in the Program/Abstract book regardless of whether the abstract will be presented in a poster or oral session. Final papers for the Proceedings of the XIV ICHM must be turned in at the Registration Desk at the Congress.

To obtain additional information about the scientific program see the ICHM website at <www.ichm.net> or contact Paul J Sheffield, PhD, ICHM Scientific Program Chairman at:

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WORLD CONGRESS OF DROWNING, 2002

To be held in Amsterdam
on 26, 27 and 28 June 2002

Breath-hold, scuba and hose diving

Recreational scuba diving is recognised as a safe sporting activity. There are relatively few accidents compared with other sports although, when an accident does occur in the water, it happens in a very unforgiving environment. What might be an insignificant incident at the surface can start a sequence of events that quickly escalates to become life threatening. The environment in which this happens is also the probable reason why up to some 60 per cent of in-water diving fatalities meet their deaths by drowning. Drowning is the *mode* of their deaths, but not the cause. In examining the *causes* of drowning in divers, one must look at the way in which people dive. To reduce the risk of drowning in divers one must address not only their in-water procedures but also basic issues such as fitness, training and equipment.

For this reason the diving community has been invited to participate in the **World Congress of Drowning** to be held in Amsterdam on 26, 27 and 28 June 2002. This conference was initiated by *The Society to Rescue Persons from Drowning* which was founded in the Netherlands in 1767.

Partners in this venture include the International Federation of Red Cross and Red Crescent, ILS (International Life Saving) and DAN.

The aims of the Congress are

to make recommendations on the prevention, rescue and treatment of drowning victims;
to stimulate and facilitate initiatives to further promote the prevention of drowning;
to reduce the number of drowning victims;
to improve the survival rate and outcome of drowning victims.

"**Breath-hold, scuba and hose diving**" (Chairman: David Elliott, UK) is thus just one of around 10 task forces convened to review particular aspects of this vast topic.

Other task forces and Chairpersons include

Epidemiology	Christine Branche, CDC, Atlanta.
Rescue	Chris Brewster, International Life Saving Federation, USA.
Resuscitation	Paul Pepe, Emergency Medicine, University of Texas.
Hospital treatment	Jean Louis Vincent, Erasmus Hospital, Brussels.
Immersion hypothermia	Beat Walpoth, University Hospital, Insel, Switzerland
Brain	David Warner, Duke University Medical Center, USA.

Each task force has an international group of experts in the appropriate specialities.

The diving task force covers the hazards associated with all types of diving. This includes recreational diving of every variety. It also covers subsistence fishermen-divers in the third world, most of whom have inadequate equipment and no proper training and who have an unknown rate of in-water incidents. The other large group is military and working divers who follow procedures that for them should make the risk of drowning negligible.

A number of drowning fatalities in divers occurs among divers who may have made an avoidable error or who may have been subjected to one. After reviewing such accidents the task force has prepared has prepared draft recommendations and reviewed those submitted by others. The following topics are among the questions that they consider deserve discussion at the World Congress.

Should diver certification last a lifetime, or is there a need for re-certification after a few years?

What changes can be recommended in the training of divers and diving instructors that might enhance diving safety?

Should a once-only medical declaration that was made before training potentially last for a lifetime?

Is there a minimum age for diving as one of a buddy-pair?

Should there be a greater emphasis at all levels of recreational diver training on the causation of known in-water fatalities?

Visit the web site (www.drowning.nl) for more details about the Congress, its task forces and the arrangements. Some 60 task force members from 20 nations have prepared formal presentations and reviewed the many recommendations for the Congress. Each task force has a summary of its proposed agenda, each will have a plenary session for all and then a number of sessions on selected diving topics.

Look through the recommendations in the diving section. Because they come from a wide range of sources, some appear worthwhile but others may not be universally acceptable. These will be discussed and, where appropriate, their implementation will be reviewed at the Congress in Amsterdam, 2002.

You can also write for more information to the
World Congress of Diving 2002 Secretariat
c/o Consumer Safety Institute
PO Box 75169, 1070 AD Amsterdam, The Netherlands.
or e-mail <Secretariat@drowning.nl>

Key Words

Breathhold diving, drowning, meeting, occupational diving, recreational diving.

LETTERS TO THE EDITOR

NON-DIVING NEUROLOGICAL PROBLEM IN A DIVER

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2002/1/8

Dear Editor

The reprinted case report on carotid artery occlusion following a dive[1] reminded me of another interesting neurological case in a diver. A professional diver in his early 40s, whom I had been seeing for his annual medical for some years, came for his 2001 medical with a fascinating story. While working offshore he had developed transient ischaemic attacks (TIAs) which were not related to his dives. After several episodes of mild hemiparesis he was investigated by a mystified medical team before his relevant past history became apparent. Some years before he had been in the armed forces and did a spell of active duty in Northern Ireland when he had been shot in the neck. The bullet was removed and he made an uneventful recovery but seemingly the carotid artery had been permanently scarred allowing a plaque to form over the years which began to generate emboli. Carotid ligation stopped his symptoms and he has successfully returned to diving and had no further symptoms.

Peter Glanvill

Reference

1 Hughes PJ. Internal carotid artery occlusion following sports diving. *SPUMS J* 2001; 31 (4): 238-240

Key Words

Case report, injury, letter, medical conditions and problems, trauma.

JACQUES MAYOL

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2002/1/22

Dear Editor

I thought it would be appropriate to draw members' attention to Jacques Mayol's obituary which appeared in the Daily Telegraph on January 10, 2002 here in the UK and from which much of the following is extracted.

Jacques Mayol was born in Shanghai in 1927 to French parents and spent the first 13 years of his life in Asia. He first became interested in diving on family holidays in Japan and was undeterred when his father died in a diving accident. As a young man he won several European contests among free divers who would cling to weighted, falling sleds and were judged purely on how deep they were able to fall. The contests were suspended after a number of participants died.

With his Italian rival Enzo Maiorca, Jacques Mayol continued to extend the boundaries of free diving, descending to 60 m off the coast of Miami in 1966, then 100 m 10 years later, the first diver to plunge so deep. He gave up diving in 1983 after he had set the world record for free diving, aged 56, by descending to 105 m, a feat of endurance which was not beaten for 13 years.

In 1984, the film director Luc Besson approached Jacques Mayol about making a film centred on his rivalry with fellow free diver Enzo Maiorca. The film, *The Big Blue* (1988) starred Jean-Marc Barr as Mayol.

His own publications include *L'Homo Delphinus – The Dolphin Within Man* (1983) and a novel, *Les dix rois de la mer* (1989). His recently published *Heritage des Peuples de la mer* describes his dives among the undersea ruins of the Yonaguni island.

Jacques Mayol died on the island of Elba aged 74.

I first became aware of Jacques Mayol's achievements in 1974 when I was working for an international deep diving company based in Italy.

It was also with this same company that in 1976 I was the Medical Officer for the Eastern Hemisphere's first commercial 300 m dive from a semi-submersible drilling rig off the west coast of Mainland Shetland. The magical imperial equivalent for this dive being, of course, 1,000 ft.

I instructed the diver and the bellman in some basic clinical observation techniques which I would be asking them to carry out just before commencing the dive.

"Oh, you don't have to worry about me," protested the diver, "I was one of Jacques Mayol's disciples".

He then proceeded to tell me about the yoga and meditation techniques which he had been taught by the maestro which included psychogenic negative feedback to the cardiovascular system causing a slowing of the heart rate and "negative pressure breathing" which resulted in fluid transfer, venous in particular, into the thoracic cavity.

Incidentally, the term “disciple” was, I believe, used by Jacques Mayol himself to describe any of his students or followers of whom there were many over the years.

In the event, when I asked the diver and the bellman to make their observations just prior to their transferring to the bell and making the dive, the diver found the bellman’s pulse rate to be about 80 bpm and the bellman noted the diver’s to be 150 bpm or so!

I was able to relate this story to Jacques Mayol when I met him in 1982, in Marseille. He was very interested to learn what had happened but as you might imagine, he was not best pleased about his disciple’s performance.

Another area in which he developed a passionate interest, which is not mentioned in the obituary, was “birthing into water”. As I recall, he told me he had spent quite some time in Moscow and the United States working with the obstetric believers and expectant mothers promoting his enthusiasm for this technique.

As far as free diving in Australia is concerned, my experience is limited to scuba diving alongside breath-hold divers off the Abrolhos Islands in Western Australia. These were non-assisted free divers who competed not so much on the basis of the depth they were able to dive to but rather their ability to catch a prescribed variety of fish using their harpoon guns. Nevertheless, these fellows who were members of the West Australian free dive team, were able to dive repeatedly to considerable depths in pursuit of their quarry.

I am not aware of any sled-assisted breath-hold diving in Australia of the type championed by Jacques Mayol but if there is and any SPUMS members are aware of it, I am sure the rest of us would like to hear about it.

Nigel I P McKie

Key Words
Breathhold diving, history, letter, records.

Editor’s comments

I cannot enlighten Dr McKie about Australian competitive breathhold diving.

However in the January 2002 issue of the British magazine **DIVER** (Vol 47 (1): 14) there is a story about Umberto Pelizzari achieving a new variable ballast (sled assisted descent with the return either finning or pulling oneself up the descent line) breathhold record dive to 125 m, which lasted for 2 minutes and 44 seconds, in November 2001.

BOOK REVIEWS

NOAA DIVING MANUAL
Diving for Science and Technology. 4th Edition.
ISBN 0-941332-70-5.
Soft cover
Best Publishing Company, P.O.Box 30100, Flagstaff, Arizona 86003-0100, U.S.A.
Price from the publishers $US 79.50. Postage and packing extra. Credit card orders may be placed by phone on +1-520-527-1055 or faxed to +1-520-526-0370. E-mail <divebooks@bestpub.com>. Also available in hard cover ($US 89.50) and as CD ROM ($US 89.00)

At 2.7 kg and over 550 pages, this text qualifies for the description “a weighty tome”. You also need a weighty purse to buy it. NOAA stands for National Oceanic and Atmospheric Administration and is part of the US Department of Commerce. As a group, NOAA employ over 300 divers who conduct more than 10,000 dives /year. The aim of the manual is to provide guidance on safe diving practices for their employees, who are mainly operating as scientific and research divers. In most areas I think the manual succeeds in meeting this aim.

Because it is written for people who will be operating in a partly self-regulated environment the manual gives some of the reasons behind their rules and recommendations. This should make it more useful to SPUMS members than a navy manual, where “thou shall not do - -” is often the statement and the end of the argument is “because the book says so”, with no explanation.

All the expected parts of a diving manual are there: Physics, physiology, equipment etc. There are chapters on training, dive planning and procedures. These cover environments like rivers, dams and caves as well as normal open sea diving. Some of these topics that may be new to most readers. I found the suggested procedures for mid-water diving interesting. These include the use of a line system to keep the divers linked to the surface. A single down line from the surface is linked to individual tether lines that feed out and retract because there are weights at the other end of the tethers. This seems a logical way of reducing line tangles. Other procedures for scientific diving cover topics like mapping, bottom sampling and even the collection of fish using anaesthetics. Pharmacologists may be interested to know these include benzocaine and chloral hydrate.

Some topics, like rebreathing equipment are not covered in great detail, but the reasons to consider their use and the problems expected with them are mentioned. Presumably NOAA intend this to be an introduction and then the diver should go away and learn from an instructor. More space is given to open circuit nitrox diving, with decompression tables for 32 and 36% oxygen open circuit diving. Methods of mixing gas and cleaning equipment for use with these gases are also covered. This apparent lack of balance is probably because NOAA took a leading part in the proving of "enriched air" diving and use it extensively. Trimix diving, using 18% oxygen, 40-50% helium, balance nitrogen is discussed but a set of tables is not supplied, possibly because they do not want to release them.

Air and nitrox saturation diving is dealt with in considerable detail. Supplied are excursion tables for use when diving from a habitat, and decompression tables to use at the end of the dive. NOAA continues to be the best source of information on this topic.

What is wrong with the book? I detected very few faults and some of these may be caused by changes that date from after the text was written. For example, the box jelly fish section still advises the use of compressive bandages and some alternatives to vinegar that probably do not work. In a few places I suspect that photographs were inserted to liven up the pages, even if they do nothing for the text. For example there is a picture of a sodalime container, a plastic container with writing on it, and a "Pool used for skin and scuba diving skills" followed by a photo of a pool. In some places we would learn more if diagrams had been used instead of photographs.

I was surprised at the inclusion of Treatment Table 8. This is a table that can take the patient as deep as 68 m (225 ft) and up to 19 hours to get back to 18 m. From there, ascent continues on Treatment Table 7. Table 8 is intended for deep uncontrolled ascents where more than 60 minutes of decompression has been missed. The USN describes Treatment Table 7 as "an heroic measure for treating non-responding severe gas embolism or life-threatening decompression sickness". It is a matter of opinion whether Table 8 is heroic or foolish. If I was involved in the use of the table, I would not be confident of getting the patient or attendant back alive except in a RCC that allows control of oxygen pressure. Without this oxygen toxicity is highly likely. I consider the table would be dangerous in most hands and NOAA might have been more rigorous in defining how and when it should be used.

Who should buy the book? Although the medical section and related topics are well done, it is written for divers, so possibly some SPUMS members might look for a more advanced text on diving medicine. But if you have to lecture divers, it is a good source and example of a suitable standard of teaching. The only problem with using it as a crib is that some text is subject to copyright while some is not and it is not clear what part is protected.

People who supervise scientific diving should have a copy, even if they have to also use an in house manual. They will find this book is a good source for background on ways of approaching scientific diving tasks and related topics. For this reason it is also a good text for people who use diving as a way of getting to work, or following some research or technical interest that requires diving to be combined with other skills.

John Pennefather
Submarine and Underwater Medicine Unit
HMAS PENGUIN

Key Words
Book review, diving operations, diving tables, equipment, nitrox, physiology, training, treatment tables.

DIVING INTO DARKNESS
THE ELEMENTS OF SAFE NIGHT DIVING

Robert N Rossier
ISBN No 0-941332-94-2. 100 pages. Soft cover.
Best Publishing Company, P.O.Box 30100, Flagstaff, Arizona 86003-0100, U.S.A.
Price from the publishers $US 14.95. Postage and packing extra. Credit card orders may be placed by phone on +1-520-527-1055 or faxed to +1-520-526-0370. E-mail <divebooks@bestpub.com>.

The sub-title more than adequately explains the content. *Diving Into Darkness* is one of the Best Publishing Company's Diversification Series and provides a wealth of information for the general diving population.

The well illustrated, 100 page book with 5 chapters covering the environment, equipment, human factors and night dive planning and procedures, is much more than a "how to" book. It is more an in depth discussion of the many factors affecting night diving safety.

Robert Rossier is a man who clearly enjoys his night diving and his passion for the subject shows up in his writing. For the diver who has yet to enjoy the night diving experience, he enthusiastically tempts the reader into venturing into the ocean after dark. His descriptions of the benefits of keeping ones torch turned off brought memories flooding back for someone whose many night dives were normally carried out without a torch.

As well as tempting us into the water with descriptions of marine life at night the author also offers an excellent explanation of the way waves act close to shore. He also delves into the interaction of wind, seas and swell, together with a discussion on how warm and cold fronts affect thunderstorm development. Very useful for the non-nautical types amongst us.

Robert's engineering background shows up when discussing lights for use at night. As well as a discussion about the various types of lights and batteries available we get a lesson in current battery and light globe technology and the good and bad points of each. General care and maintenance is also well covered as is support equipment and equipment rigging tips.

The chapter on night dive planning and procedures is standard fare for those with plenty of experience in the field. However, it provides many insights into the nuances of preparing your dive site and underwater navigation at night, a couple of activities that can be daunting prospects for the night dive novice.

For my money the best section, although probably the shortest, is the one on human factors. For someone who spent much of his younger life working at strange hours and being told "just get in the water" this was excellent stuff. In the navy we did not take nutrition, circadian rhythms or shifts in heat balance into account. We just dived when we were told to. All divers can learn a lot about what is happening to their bodies when night diving from this chapter. Making mention of major industrial accidents tending to happen at night when reactions are sluggish and people are fatigued brings home the need to take extra care and increase concentration levels.

All in all an excellent little book, basic enough for the novice to learn from and yet with enough information to be a handy reference for the experienced night diver. I would have no hesitation in recommending *Diving into Darkness* to any diver wishing to dive into darkness.

Steve Goble

Key Words

Book review, diving operations, recreational diving.

SOLID BRASS

Written and Illustrated by Bob Wick

Best Publishing Company, P.O.Box 30100, Flagstaff, Arizona 86003-0100, U.S.A.

Price from the publishers $US 17.75. Postage and packing extra. Credit card orders may be placed by phone on +1-520-527-1055 or faxed to +1-520-526-0370. E-mail <divebooks@bestpub.com>.

This is a book of reminiscences from a master diver. He is not internationally famous for any specific exploits, but is probably well known in the areas in which he has undertaken diving activities, such as the US Navy Diving branch, Californian abalone diving industry, and the oil rigs.

The book is designed to follow Bob Wick's diving experiences chronologically and in this he has been reasonably disciplined. It tracks his career through US Navy diver training units, into the operational teams, then into the even less disciplined and more adventuresome abalone diving off Southern California. His experience in the oil exploration industry and maintenance activities were carried out mostly off California and in Alaska.

He describes the difficulties encountered in underwater demolition training (UDT) training, and although it appears that he may never have been in active military service against an enemy, the diving was dangerous by any standards, as it was everywhere in those days.

He depicts the diving operations accurately and this may be of interest to many readers. It is brimming with fascinating subjects, written from a diver's perspective and with a diver's humour, but written badly.

Solid Brass is essentially a diver's book of yarns. They are type of the stories that are told whenever divers meet, especially around barbeques and in pubs. Unfortunately these stories are usually more interesting when presented in person rather than depicted on paper. Such is the case here. Some of the stories probably have a kernel of truth, with often amusing hyperbole. Others would only have meaning to the people involved. Unfortunately the author has not differentiated and selected these.

Those readers who have undergone clearance diver training (UDT in the USA), or who have lived in the areas that he describes, or mixed with his friends, would certainly find the book interesting, as I did. Clearly, some of the stories have grown and been crystallised over the years of telling. The flamboyant exaggerations are fairly typical of experienced and sometimes garrulous divers.

The attitude of Bob Wick is not at all dissimilar to that of many other highly qualified and capable divers. He certainly illustrates the psychological adaptive characteristic of personal capability and denial, denying or rejecting the dangers and ambiguities that many other less experienced or more aware divers would feel.

His irreverent attitude toward authority is, again, fairly typical of divers. Having spent 9 years in the Royal Australian Navy diving sector, I felt that his naval misdemeanours as described were fairly innocuous by Australian standards. Like most divers he either had a strongly positive or strongly negative attitude towards his specific superiors, fitting in with the black and white judgments that tend to be made by naval divers.

To pad the book out he has added many other stories of a non-diving nature, such as experiences with circumcision and bullfights and others which only have a distant connection to diving, such as fishing with explosives. Again, these stories would go well over a camp fire, or in a pub. The stories have a fairly constant theme, involving very demanding environmental circumstances, initiative and improvisation and a type of raw humour, sometimes coarse in nature.

His life was full of Boys-Own type adventures, alcohol excess and fighting. At one stage he describes his beer as "the days supply of personality" and there is probably an element of truth in this.

The black and white photographs have been reproduced with a bland sepia quality and are often not very relevant to the text. They could have been enhanced by greater contrast. Of course, photographs taken decades ago often do not survive and reproduce very well. Whether this is the fault of the original photographs or the printing, I am not sure. Nevertheless, other photos were of interest and the book was improved by their inclusion.

Illustrative diagrams are included, but are neither of great quality nor of interest. They could have been improved by a professional illustrator.

I am sure the motivation for the book came from his family. I would imagine that they admire him and his ability to survive extremely hazardous conditions. I would also admire this ability. I believe that he would be an enjoyable and entertaining companion.

This is a book, looking back at a diving career of over 40 years, for those who are already experienced in the diving industry in the geographical areas described or those who would like to look back, from the comfort of an armchair, at a way of diving that has almost completely disappeared as commercial diving has been forced to accept safety protocols.

Carl Edmonds

Key Words

Book review, general interest, history, occupational diving.

DANGER'S HOUR

James Francis

ISBN 0 7322 7004 9

HarperCollins*Publishers*

RRP $Aust 45.00.

At the end of his presentation "Survival in a Disabled Submarine" at last year's Annual Scientific Meeting in Madang, James Francis put up a slide of the cover of *Danger's Hour* and promised us all a "rollicking good read". A promise he certainly delivers.

An action novel about the disabling and sinking of a US Navy submarine in the waters off Norway, this story has many similarities with the Kursk disaster. However, *Danger's Hour* was written before the Kursk sank and James acknowledges the similarities at the beginning of the book.

As can be expected from an expert in the field, this book delivers a rare insight into the difficulties experienced trying to survive in a crippled submarine. It also shows up the deficiencies of the various rescue systems available and their dependence on the prevailing weather conditions.

Having spent my fair share of winters in the northern half of the North Sea I can attest that James's descriptions of cold, wintry, storm force conditions are extremely accurate. As are his descriptions of launching and retrieving a submersible in those conditions. In fact all of his descriptions of the various rescue vessels and their behaviours are very believable.

Without wanting to give away too much to those yet to read the book. One can really imagine the terrible conditions endured by the survivors as it gets colder, the carbon dioxide levels increase, the humidity increases, the pressure increases, the injured deteriorate and morale drops. Apparently the author was involved in trials simulating exactly those conditions to gauge the effect on personnel trying to await rescue in a disabled submarine.

Where readers should get concerned, especially if they are American taxpayers, is when reading of the US Navy's total reliance on the nuclear reactor. It is all very well having a bank of batteries to back up your electricity supply but not having any emergency communication or atmosphere control equipment capable of running on DC power is totally negligent. Carbon dioxide scrubbing units with 24 volt AC/DC motors have been around for over 25 years. Similarly, through water communication systems running on battery power have been an integral part of diving bell emergency equipment for a similar period.

Of equal concern is the discovery that the US Navy is still using submarine escape apparatus that dates from 1953. The Steinke Hood, as its name suggests, is basically a hood. Covering the entire head it provides limited buoyancy and no thermal protection, hardly what is required when trying to escape into very cold water in the middle of a winter storm. Readers may be interested to learn that the US Navy is in the process of joining 22 other navies and changing over to the British Mark 10 Submarine Escape and Life-raft Equipment hoping to finish in 2007.

This updating of emergency and escape equipment was delayed because during the cold war submarines spent much of their time in areas where a sinking would have taken them either below crush depth or at least to a depth where escape was impossible. Therefore a great deal of time, effort and money was lavished on the Deep

Submergence Recovery Vehicle. Catering for having a submarine disabled at shallower depths did not fit the equation and was largely overlooked.

Back to the story, *Danger's Hour* races along at a tremendous pace, it is one of those books that are difficult to put down. There is an excellent glossary for those unused to military terminology and an explanation of time zone abbreviations for those uncertain of how Alpha or Romeo time relates to the USA or Scandinavia.

Having read many action novels involving diving and submarines over the years, it is refreshing to read one that not only has an excellent story line but is also factually accurate. While this may not bother many readers, it makes the read all the more enjoyable for those with any knowledge of the subject.

Danger's Hour is available in most places books are sold and James Francis is to be congratulated in coming up with such an outstanding story for his first book.

Steve Goble

Key Words

Book review, general interest, submarine.

PROCEEDINGS OF THE ELEVENTH ANNUAL CONFERENCE OF THE HISTORICAL DIVING SOCIETY, LIVERPOOL 2001

Edited by Nigel Phillips
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E-mail <info@thehds.com>
Price from the publisher £4 .50 plus postage £1.50.

Inside the front cover are the words, The Historical Diving Society, Promoting and Preserving our Diving Heritage. This phrase sums up the proceedings of their 11th Annual Conference, held in the Liverpool Maritime Museum on 2001/10/27.

I must admit my bias, I am interested in the history of diving and how it has developed. Now that the Historical Diving Society (HDS) has produced this fascinating record of their one day conference the proceedings are available to anyone who wants to pay for the book. In my book it is very good value for approximately $Aust 18.00.

Those attending the conference were treated four very interesting topics. Andre Galerne's A Diving Life leads from pre-war France, the Resistance, founding his first diving company, moving to Canada and starting a diving company, International Underwater Contractor there, then to the USA to found IUC International which among other things operated diving vessels, submersibles and remotely operated vehicles (ROVs). Andre's life spans the modern occupational diving world. His presentation is a personal view of the interesting spots in his life in diving. One of the best stories is the description of how he and John Rawlings, who became a Vice-Admiral, Sir John and Medical Director General of the Royal Navy, persuaded reluctant diving contractors that their new baby, a helicopter transportable recompression chamber, could in fact hold the six persons that they claimed. It looked far too small. However the pair chose four other "six footers" (1.8 m or more) from the audience and got them to sit in the chamber on the benches. With them shoehorned in Andre lay on the floor and John Rawlings lay on top of him, and the door could be shut. Not quite a bit of overkill, but certainly a winning hand.

The next speaker Ian Fraser VC, spoke of his life in the Royal Navy working in midget submarines. From his understated story life in these tiny vessels was clearly uncomfortable beyond the norm for submarines. Four men shared a very small space which also contained a lock out compartment for the diver crew member to leave and endter the boat. As the divers used oxygen rebreathers, often at depths which guaranteed cerebral oxygen toxicity, the were fatalaties from time to time. The story of his X-craft's successful attack on a Japanese cruiser lying in Johore Strait towards the end of World War II, is too interesting to put down before the end.

John Bevan, who was a Guest speaker at the 1998 SPUMS ASM in Palau, spoke about the Liverpool and Glasgow Salvage Association from 1857 to the present day. Wrecks and strandings were common in the days of sail and divers were often needed to raise ships and salvage cargo. The First World War saw a vast increase in work for salvors and ship repairers. These few words do no justice to 13 pages of very interesting reading.

The final speaker was John Towse, whose name is almost synonymous with the Royal Naval Physiological Laboratory. His Under Pressure is the story of the RNPL, an establishment which produced many diving physiology firsts. John Bevan, David Elliott, Peter Bennett, John Rawlins and Val Hempleman all appear in his tale, as do many, many other well known diving physiology investigators. The paper is a quite fascinating mini biography of an institution.

I strongly recommend those interested in diving history to splash out and buy the book.

John Knight

Key Words

Book review, general interest, history, occupational diving.

SPUMS ANNUAL SCIENTIFIC MEETING 2001

BREATHHOLD DIVING

James Francis

Key Words
Breathhold diving, hypoxia, unconscious.

Abstract

Breathhold diving has been practised for millennia. Until the advent of the diving bell and underwater breathing apparatus it was the only way that man could harvest food and valuable items such as sponges and pearls from the sea. Although there are still commercial breathhold divers, breathhold diving has largely changed into a sport. Among these sportsmen there is a cadre of elite divers who devote themselves to diving ever deeper. There are a number of physiological constraints that need to be overcome to undertake very deep dives. It was once thought that thoracic squeeze was the main limitation to how deep a breathhold diver could go. As this theoretical limit was exceeded in the 1960s other parameters have become limiting. This brief review examines breathhold break points and techniques for extending a breathhold dive, possible adaptation to breathhold diving and loss of consciousness during ascent.

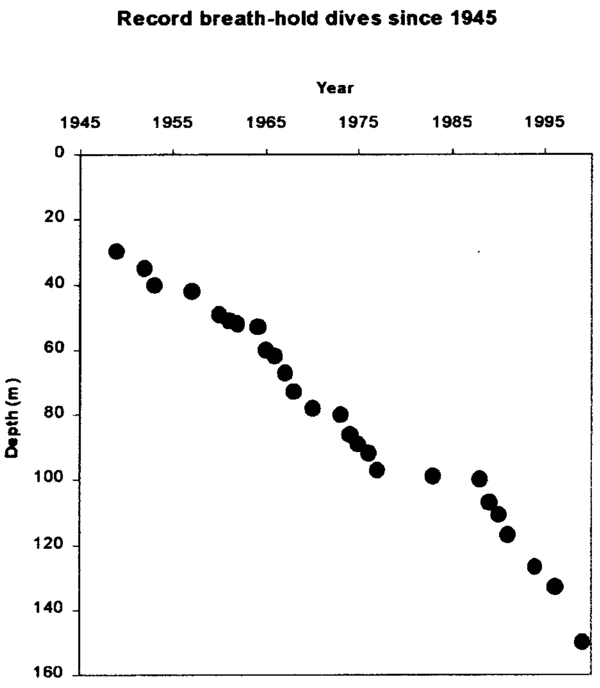

Figure 1. Record breath-hold dives since 1945.

Introduction

The idea of venturing underwater without a supply of breathing gas is increasingly alien to a western world that is more aware than ever of the undersea environment. Through film and television people who have never ventured into water deeper than their knees have become familiar with scuba and other diving apparatus to the point that some find even the idea of free diving frightening.

The fact is that for most of man's evolution, breathhold diving was the only technique available for exploring underwater. For many centuries it was the way in which lost items were recovered and food and valuables, such as pearls and sponges, were harvested from the sea, practices which persist to this day in parts of the Far East.

Today, most free diving is conducted as a sport and its elite practitioners are devoted to diving ever deeper. Figure 1 shows graphically how, since WWII, ever deeper records have been set. Two techniques are used: the first is an "unassisted" dive whereby the diver descends and ascends using their own power, either finning or pulling hand-over-hand up and down the shot line. "Assisted" dives are those where the diver uses a weight or sled to increase the rate of descent and a buoyancy aid to speed their ascent back to the surface. At the time of writing the record, assisted dive was held by Umberto Pelizzari, who dived to 150 m in October 1999. In the same week, he also claimed the unassisted dive record of 80 m.

In the remainder of this paper I will describe some of the physiological factors associated with this kind of diving.

Thoracic squeeze

Gas in the lungs obeys Boyle's Law and consequently, during descent, it will decrease in volume in proportion to the depth achieved. It was once believed that if the volume of gas in the lungs was compressed to less than the residual volume (RV) of the lungs then a relatively negative pressure would develop in the chest and thoracic "squeeze" would occur. This would result in pulmonary oedema, frank haemorrhage into the lungs and, in extremis, death.

In most people, if a full breath is taken at the surface, the lung will reach residual volume at a depth of 30-50 m. In the mid-1960s deeper breathhold dives were being achieved. Schaefer et al. studied Robert Croft, a US Navy diver who had reached a depth of 73 m. His total lung capacity (TLC) was 9.11 litres with an RV of 1.31 l.[1] Theoretically the maximum that he should have been able to dive and avoid lung squeeze was 69.5 m. They found

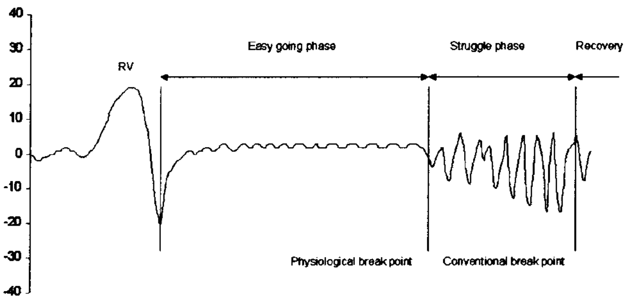

Figure 2. After breathing out to residual volume, a breath is taken and held. During the easy going phase of the breathhold there is little respiratory muscle activity. As the central drive to breathe increases the physiological break point is reached and involuntary respiratory muscle activity starts. This increases until the conventional break point is reached, and a breath is taken. (Adapted from Reference 2).

dives take as long as three minutes or longer to complete. Figure 2 shows a recording of oesophageal pressure during a breathhold at the surface. There are two distinct phases. During the first there is little respiratory muscle activity and this ends at the physiological break-point. During the second phase, respiratory muscle activity gradually increases until the breathhold is broken at the conventional break point.[3] The physiological break point is reached largely involuntarily. It occurs when the alveolar pressure of carbon dioxide (P_ACO_2) reaches about 46 mm Hg. The duration of this phase can be extended by increasing the volume of the lungs at the start of the breathhold or by blunting the hypercapnic respiratory drive by inhaling 100% oxygen prior to the breathhold.[4] The duration of the struggle phase has a substantial voluntary component and is determined by many more factors (Table 1).

TABLE 1

FACTORS AFFECTING THE DURATION OF EACH PHASE OF A BREATHHOLD DIVE

Easy-going phase	Struggle phase
Lung volume at start of breath-hold	Immersion
Oxygen content of the gas breathed	Water temperature (if immersed)
Arterial PCO_2 (and PO_2)	Mechanoreceptor stimulation:
	Rebreathing
	Releasing air
	Valsalva manouvre
	Distracting activity:
	Physical
	Mental
	Arterial PCO_2 (and PO_2)
	Tolerance to hypercapnia and hypoxia:
	Training
	O_2 and CO_2 stores:
	Hyperventilation
	Oxygen breathing

that, during a breath hold dive, his thoracic blood volume (TBV) increased by between 850 and 1,047 ml. The equivalent figures for Jacques Mayol, another record-breaking free diver, were TLC 7.21l, RV 1.88l.[2] To achieve his record dive of 70 m, it was calculated that he would have to increase his TBV by 980 ml. Increasing the TBV has the effect of reducing the residual volume and thereby greatly increasing the maximum depth that can be achieved.

Breathhold break points

To undertake a successful breathhold dive, the diver must be capable of holding his or her breath for a considerable period. Even using assisted techniques, deep

However, as with the physiological break point, the P_ACO_2 is an important determinant. Consequently, the fundamental physiological determinants of a breathhold duration are the metabolic rate and the capacity of the CO_2 store. Superimposed on this will be individual's tolerance to hypercapnia and hypoxia.

Immersion in water can increase the duration of a breathhold by about 26%, although this effect is highly dependent on the temperature of the water.[5] The maximal effect is seen during immersion in thermoneutral water. The mechanisms involved are unclear. One possibility is an acute increase in carbon dioxide stores.[6] The role of the oxygen conservation and other metabolic consequences of the dive reflex in man is controversial.[7,8] The duration of breathholding can be shortened dramatically by immersion

TABLE 2

HUMAN OXYGEN AND CARBON DIOXIDE STORES[13,14]

Oxygen stores (litres)		**Carbon dioxide stores (litres)**	
Haemoglobin			
Venous blood	0.60	Bone	106.5
Arterial blood	0.28	Muscle	9.5
Myoglobin	0.24	Other tissues	7.0
Dissolved in tissues	0.06		
Lung (at FRC)	0.37		
TOTAL	**1.55**	**TOTAL**	**123.0**

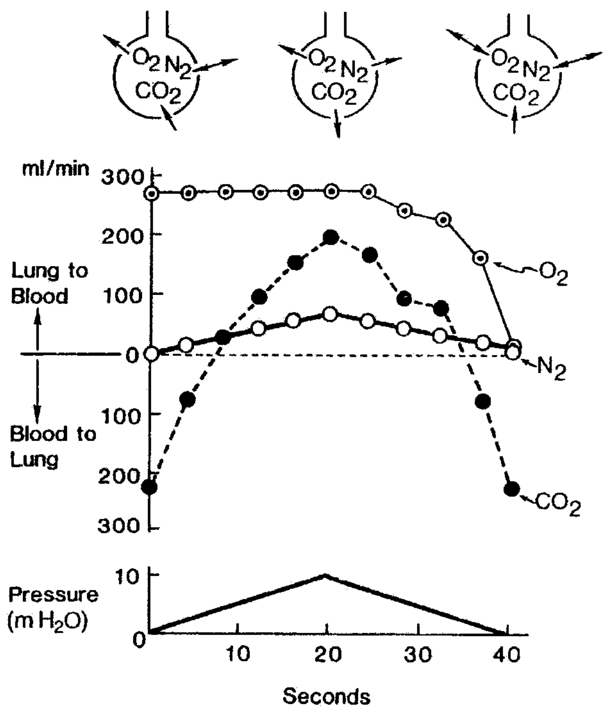

Figure 3. The rate of alveolar O_2, CO_2 and N_2 exchange during a breathhold dive to 10 m. (From Reference 23).

in cold water. Five subjects immersed in water of 20°C could only hold their breath for about 40% of the duration of a control, non-immersed breathhold.[5] This shortening of the breathhold time is probably due to two effects: the direct stimulation of skin cold receptors and the increased metabolic rate caused by immersion in cold water.[3,9]

A breathhold can be extended by rebreathing from a bag. Whitelaw et al. have shown that a higher P_ACO_2 and lower alveolar oxygen pressure (P_AO_2) can be tolerated by stimulation of thoracic mechanoreceptors.[10] This may explain why trained breathhold divers perform Valsalva manoeuvres or release air from the lungs to extend their breathhold time. Distracting physical or mental activity such as squeezing a rubber ball or doing mental arithmetic can also be used to prolong a breathhold.[11,12]

Another means of increasing the duration of a breathhold is by increasing the store of available oxygen in the body and postponing the rise in the arterial carbon dioxide pressure (P_aCO_2) by increasing the capacity of the body's carbon dioxide stores. Table 2 shows the extent of these stores in a 70 kg man. The first and obvious point to make is that the carbon dioxide stores are two orders of magnitude greater than those of oxygen. The oxygen stores can be increased by three strategies: Hyperventilation can increase the alveolar oxygen content by about 0.15 litres and the pulmonary oxygen store can be increased by another 0.5 litres by starting the breathhold at TLC rather than FRC. The biggest effect, however, is achieved by breathing oxygen. If the final breath before the breathhold (from RV to TLC) is taken using 100% oxygen, the pulmonary oxygen store can be increased by between 3.5 and 4.5 litres in a healthy adult male. The carbon dioxide storage capacity can be increased quite simply by blowing off CO_2 through hyperventilation. Taking twenty deep breaths in a minute will blow off about 1.4 litres of CO_2. This exceeds eupneic CO_2 elimination by about 1.1 litres or roughly 4 minutes of CO_2 production. Using a combination of hyperventilation and oxygen breathing an average male can increase his breathhold duration from about 2.5 to 12 minutes.

Adaptation

There is some evidence that training can increase breathhold duration. Schagatay and Andersson studied nine groups of subjects with varying degrees of experience of breathhold diving.[8] They showed that young, trained breathhold divers could tolerate the longest apneas (and greatest reduction in heart rate and skin blood flow) compared with groups of older and inexperienced divers and non-diving controls. Ferretti et al. found the same in a study of three elite breathhold divers and nine controls.[15] How this adaptation occurs remains unclear. Elite divers are able to tolerate a lower P_AO_2 and arterial oxygen saturation than controls and are more tolerant of CO_2. Reduced sensitivity to CO_2 has been shown in Korean diving women, Japanese Ama and underwater hockey players.[16-19] The question remains whether this finding is an example of adaptation or whether people with low sensitivity to CO_2 self-select for breathhold diving occupations or pastimes.

It is well known that diving using underwater breathing apparatus is associated with an increase in vital capacity.[20-22] The same phenomenon has been found in

TABLE 3

ALVEOLAR GAS COMPOSITION IMMEDIATELY BEFORE DESCENT, ON THE BOTTOM AND IMMEDIATELY AFTER RETURNING TO THE SURFACE AFTER A 10M BREATHHOLD DIVE[23]

	Alveolar Gas Tension (mm Hg)	Alveolar Gas Fraction (%)
Surface		
O_2	120	16.7
CO_2	29	4.0
N_2	567	79.3
10 m		
O_2	149	11.1
CO_2	42	3.2
N_2	1143	85.7
Surface		
O_2	41	5.9
CO_2	42	5.9
N_2	631	88.2

exchange of oxygen, carbon dioxide and nitrogen during a 10 m breathhold dive lasting 40 seconds. It can be seen that, towards the end of the dive, there is virtually no exchange of oxygen from the lung to the blood. Table 3 (page 29) shows the effect of this gas exchange on the gas tensions in the lung. On longer dives the partial pressure of oxygen in the lungs falls sufficiently that the direction of oxygen exchange can reverse and the lungs actually remove oxygen from venous blood.

Table 4 shows the effect of hyperventilation prior to a breathhold on end-tidal gas tensions. It shows the extent to which a resting and exercising breathhold can be extended by hyperventilation. Note that the end tidal oxygen pressure ($P_{ET}O_2$) at the end of breathholds preceded by hyperventilation is significantly lower than in those which were not. As was discussed above, the reason for this is that hyperventilation increases CO_2 storage capacity far more than it increases the body's O_2 stores. We have seen in Table 3 that the alveolar oxygen tension is maintained on the bottom by the effect of pressure. Consequently it is the P_aCO_2 which is the primary determinant of the breathhold break point underwater and, with it, the signal for the diver to return to the surface. It follows that, having extended the time underwater, the alveolar oxygen tension may fall to dangerously low levels during ascent to the point that the diver may lose consciousness. Not only may the diver drown in such circumstances, but it is this effect rather than lung squeeze, which limits how deep man can dive without the use of breathing apparatus.

TABLE 4

HYPERVENTILATION AND BREATH-HOLD BREAK POINT[24]

Measurement	Normal breath		Hyperventilation	
	Rest	Exercise	Rest	Exercise
Breath-hold time (second)	87	62	146	85
End Tidal CO_2 (mm Hg)				
Start	40	38	21	22
At break point	51	54	46	49
End Tidal O_2 (mm Hg)				
Start	103	102	131	130
At break point	73	54	58	43

the Japanese and Korean Ama.[16,18] Again, it is unclear whether this is cause or effect, because having a large VC would confer an advantage in terms of the capacity of the pulmonary oxygen store. In addition, a high VC/RV ratio would theoretically reduce the risk of thoracic squeeze although, as we have seen above, this effect is probably of no practical significance.

Loss of consciousness on ascent

Alveolar gas exchange during a breathhold dive is determined by the body's metabolism and the effect of pressure. Figure 3 illustrates the direction and rate of

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SIMULATIONS OF NEAR-DROWNING AND DECOMPRESSION SICKNESS: A PRELIMINARY STUDY

Chris Acott and David J Doolette

Key Words

Decompression illness, near drowning, oxygen, physiology, simulations, treatment.

Abstract

Theoretically near-drowning should decrease inert gas elimination from tissues by a reduction in cardiac output and increased intrapulmonary shunting. A delay in inert gas elimination may prolong tissue supersaturation and so

increase the risk of decompression sickness (DCS). However, there are no data on inert gas elimination or the incidence of decompression sickness in near-drowned compressed air divers. Resuscitation might also retard inert gas elimination because of the adverse cardiovascular effects of intermittent positive pressure ventilation (IPPV) and positive end expiratory pressure (PEEP).

Decompression modelling, using Linear-exponential kinetics, of near-drowning scuba dive accident scenarios have shown an increased risk of DCS for no-stop dives to above the acceptable level of risk of 2.3% used by the United States Navy. Modelling of resuscitation following near-drowning demonstrated that there is no further increase in DCS risk provided the cardiac output was normal before IPPV and PEEP were instituted.

All compressed air divers, who have near-drowned, except those who have a minimum disturbance of shunt and cardiac output, should be carefully assessed with regard to decompression risk and treated appropriately. Divers who had been resuscitated from a cardiac arrest or are severely shocked at presentation should be recompressed because of the risk of decompression sickness is increased to between 25 and 52%.

Introduction

Near-drowning should theoretically decrease inert gas elimination from a reduction in cardiac output, leading to reduced tissue perfusion, and an increase in pulmonary areas of low ventilation perfusion ratios, increased anatomical shunt, or a combination of both (collectively intrapulmonary shunt).[1,2] A delay in inert gas elimination would be expected to prolong tissue supersaturation and so increase the risk of decompression sickness (DCS). However, there are no data on inert gas elimination nor the incidence of decompression sickness in near-drowned compressed air divers.

Anecdotal reports indicate there is a decrease in cardiac output and an increased intrapulmonary shunt following near-drowning in humans but there are no reliable published data. Some victims may suffer a cardiac arrest but respond to cardiopulmonary resuscitation and will have cardiac output as low as 30%. There are also limited data on the magnitude of increase in shunt in near-drowned victims, however, there is one report that the shunt could increase to 75%.[3] Experimental studies in animals indicate decreased cardiac output and increased shunt following near-drowning.[4,5]

Resuscitation may initially retard inert gas elimination in a patient with compromised cardiovascular and respiratory systems. Intermittent positive pressure ventilation (IPPV) and positive end expiratory pressure (PEEP) are associated with a decrease in cardiac output and blood pressure due to an impaired venous return, decreased ventricular filling, increased pulmonary vascular resistance and altered configuration and compliance of the right and left ventricles even in patients without significant pulmonary pathology.[6,7]

Recompression and hyperbaric oxygen may also initially depress inert gas elimination if applied in a patient with decreased left ventricular function due to an increase in systemic vascular resistance, decrease in left ventricular contractility, increased after load, centralisation of blood volume and an imbalance between right and left heart function worsening pulmonary oedema.[8]

Since there are no experimental data on incidence of DCS in near-drowning we have made a theoretical evaluation on the risk of DCS using probabilistic decompression modelling. Probabilistic decompression modelling involves the "fitting" of a decompression model to a large data set of dive profiles (depth/time/breathing gas history) with known outcomes (DCS or no-DCS) using a non-linear regression procedure. Such a probabilistic decompression model assigns a probability of DCS to each dive profile. This probability is a function of the duration and the degree of tissue supersaturation.[9-11] These models present a theoretical framework for organising decompression experience, but are not an accurate description of the physiological and pathophysiological pathways of DCS. The most successful statistical decompression algorithm for air or nitrox mixtures up to 40% oxygen to date is the USN linear-exponential model (LE1). In this model 2,383 dives with an incidence of 131 cases of decompression sickness, and 75 "marginal cases", are used. In this paper we modified the USN LE1 model by combining it with a model of the cardio-pulmonary system which allowed arterial nitrogen tension to be modified by cardiac output and pulmonary shunt and used the resulting model to examine the effects of hypothetical near-drowning scenarios on probability of DCS.[9,12]

Definitions

We have defined **drowning** as death by submersion in a fluid with or without aspiration of fluid. **Near-drowning** is defined as survival following aspiration of large quantities of fluid or survival following unconsciousness while submerged in a fluid.

Method

Three square and 2 multi-level dive profiles were chosen because 2 South Australian dive sites near Adelaide provide such diving. The no-decompression times were derived from the Canadian Defence and Civil Institute of Environmental Medicine (DCIEM) decompression tables for the multi-level dives (D and E) and two (A and B) of the square dives and from the United States Navy (USN) decompression tables for the other (C) square dive. All profiles were calculated for no-stop ocean diving.

A 18 m for 50 minutes (DCIEM).
B 30 m for 15 minutes (DCIEM).
C 30 m for 25 minutes (USN).
D a multi-level dive of 18 m for 50 minutes followed by 12 m for 30 minutes and then 6 m for 30 minutes.
E a multi-level dive of 18 m for 50 minutes followed by 12 m for 30 minutes and then 6 m for 5 minutes.

The resuscitation simulations were based on the clinical experience of near-drowning victims and diving accidents of one of the authors (CJA).

Intrapulmonary shunt of 5% (normal), 50% and 70% and cardiac output of 100% (normal), 50% and 30% were simulated for the different dive profiles and near drowning scenarios.

For the simulation it was assumed that the diver near-drowned at the end of the dive.

a After 15 minutes or 45 minutes, representing retrieval to the boat and to oxygen, on-site resuscitation was started using of 0.6 bar oxygen.
b During transfer from the boat to the hospital 2 hours from the end of the dive, the victim then breathed 0.6 bar of oxygen.
c After admission to the Intensive Care Unit (ICU) 1.0 bar oxygen was administered for another 10 hours. We assumed that ICU management was successful and that the patient improved steadily. By the end of this time the victim's cardiac output and pulmonary function had returned to normal.

Another resuscitation simulation involved the patient receiving 0.6 bar oxygen from 15 minutes after surfacing from dive A until hospital was reached 2 hours later. The victim's cardiac output remained normal during this time but intrapulmonary shunt was 70%. In hospital intermittent positive ventilation (IPPV) and positive end expiratory pressure (PEEP) were applied with 1 bar oxygen resulting in a transient fall in cardiac output to either 50 or 30% of normal followed by a slow return to normal over an hour. This simulation was used to see if the effect of a sudden fall in cardiac output with the use of PEEP and IPPV increased the risk of decompression sickness during resuscitation.

The probability of DCS for simulated dive profiles was calculated using a modified USN linear-exponential algorithm (LE1). In the LE1 algorithm the probability of DCS associated with any diving exposure is calculated by tracking gas tensions in arterial blood and in 3 parallel perfusion limited compartments with different rate constants. Uptake of gas into the compartments is exponential and elimination is either exponential or linear. Linear kinetics and positive instantaneous risk may occur during and after decompression if compartment dissolved gas tensions exceed a threshold value above ambient pressure. Probability of DCS results from the time integral of the instantaneous risk in the 3 compartments.

The algorithm used in the present report similarly calculates probability of DCS from 3 compartment linear-exponential model using parameters described in 1997 by Thalmann et al.[10] and an implementation similar to that described by Gerth and Vann in 1997,[11] but differs in how arterial nitrogen tension is calculated.[12] Both algorithms calculate inspired nitrogen partial pressure from the depth/time/breathing gas history. The original LE1 algorithm assumes that arterial nitrogen tension equals alveolar nitrogen partial pressure and predicts the latter from inspired nitrogen partial pressure using the alveolar gas equation and assuming a respiratory quotient of 1.[13] The current algorithm incorporates a model of the cardio-pulmonary system to calculate arterial nitrogen tension.[12] In this model inspired gas, alveolar gas, pulmonary blood and the body are in series, the latter composed of 4 parallel compartments representing vessel rich, muscle, fat, and vessel poor tissue groups with blood flows and compartment volumes based on the standard 70 kg man.[14,15] The model uses nitrogen tissue/gas partition coefficients of 0.015 (blood), 0.015 (lean), 0.075 (fat) and lung nitrogen diffusing capacity of 0.15 L/min/kPa.[14-16] Pulmonary blood flow (cardiac output) and intrapulmonary shunt can be manipulated. Arterial nitrogen tension is therefore not only a function of depth/time/breathing gas history but also distribution of nitrogen into the body tissues, cardiac output, and pulmonary shunt. Tissue compartment blood flows (and therefore rate constants) in both the cardio-pulmonary model and the linear-exponential risk model components of the algorithm were considered to vary in proportion to cardiac output. Simulations were performed using Scientist for Windows version 2.01 (Micromath Inc.).

Results

The risk of DCS was calculated for the (non-drowning) profiles using Linear-exponential kinetics. The calculated risk for each of these dives is: (A) is 1.7%, (B) is 2.1%, (C) is 2.1%, (D) and (E) 2.7%. The results for the near-drowning scenarios are shown in tables 1 to 7. The "normal" values reflect the risk if oxygen is breathed as described above for 12 hours from the end of the dive with no changes in intrapulmonary shunt or cardiac output.

The resuscitation simulation (Dive A with 0.6 bar oxygen after 15 minutes with a normal cardiac output and a 70% shunt followed by 1 bar oxygen with IPPV and PEEP when a hospital is reached) did not change the risk compare to that shown in Table 1.

Table 1

Risk of DCS associated with Dive A. 18 m for 50 minutes (Within DCIEM no-stop limits). No oxygen for 15 minutes after surfacing.

	Normal	50% Shunt	70% Shunt
Normal	1.5%	2.5%	3.8%
70% Cardiac Output		3.5%	6.1%
50% Cardiac output	2.3%	4.9%	13.6%
30% Cardiac output	3.3%	9.3%	52.6%

Table 2

Risk of DCS associated with Dive A. 18 m for 50 minutes (Within DCIEM no-stop limits). No oxygen for 45 minutes after surfacing

	Normal	50% Shunt	70% Shunt
Normal	1.5%	3.0%	5.3%
50% Cardiac output	2.5%	7.4%	18.9%
30% Cardiac output	3.4%	14.2%	57.4%

Table 3

Risk of DCS associated with Dive B. 30 m for 15 minutes (Within DCIEM no-stop limits). No oxygen for 15 minutes.

	Normal	50% Shunt	70% Shunt
Normal	1.5%	1.9%	2.5%
50% Cardiac output	2.0%	3.3%	6%
30% Cardiac output	2.7%	5.7%	25.7%

Table 4

Risk of DCS associated with Dive B. 30 m for 15 minutes (Within DCIEM no-stop limits). No oxygen for 45 minutes.

	Normal	50% Shunt	70% Shunt
Normal	1.5%	1.9%	2.5%
50% Cardiac output	2.1%	3.4%	7.8%
30% Cardiac output	2.8%	6.3%	32.6%

Table 5

Risk of DCS associated with Dive C. 30 msw for 25 minutes (Within USN no-stop limits). No oxygen for 15 minutes.

	Normal	50% Shunt	70% Shunt
Normal	1.6%		3.1%
50% Cardiac output		3.9%	
30% Cardiac output	3.2%		35.2%

Table 6

Risk of DCS associated with Dive D. Multi-level 18 m for 50 minutes, followed by 12 m for 30 minutes and 6 m for 30 minutes. No oxygen for 15 minutes.

	Normal	50% Shunt	70% Shunt
Normal	1.3%		
50% Cardiac output		4.1%	9.6%
30% Cardiac output			48.2.7%

Table 7

Risk of DCS associated with Dive E. Multi-level 18 m dive for 50 minutes, followed by 12 m for 30 minutes and 6 m for 5 mintues. No oxygen for 45 minutes.

	Normal	50% Shunt	70% Shunt
Normal	1.3%		
50% Cardiac output		4.4%	11.9%
30% Cardiac output			52.0%

Discussion

Probability of DCS increased in all the near-drowning scenarios. The USN uses 2.3% risk from their LE1 model to define acceptable dive profiles.[17] This was exceeded in the majority of scenarios modelled. In the worst scenarios the risk of DCS increased to between 25 to 58%.

This model demonstrated that, in isolation, increasing either the shunt fraction or decreasing the cardiac output increase the DCS risk by similar amount. When these two are combined the increased DCS risk is greatly enhanced. There are few published measurements of these parameters following near-drowning in humans. However, animal data supports the range of values chosen in this study. Experimental models of near-drowning in pigs and dogs have shown increase in pulmonary shunt to near 70% and depression of cardiac output to 75%.[4,5] The combination of the 70% increase in shunt fraction and reduction of the cardiac output to 30% would be represented by a severely shocked patient or one who has responded to CPR following a cardiac arrest.

In the simulated dives the DCS risk incidence is greater in the shallower longer dives. These longer dive profiles would allow a greater uptake of inert gas in slower tissues resulting in a prolonged supersaturation and therefore greater risk. However, extending the shallower dive into a multi-level dive did not greatly increase the risk following near-drowning. We have not systematically investigated the reasons for this.

During the resuscitation phase the increased DCS risk varied with the timing of oxygen administration. This effect was noted more in the longer shallower dive.

The early administration of oxygen attenuated the risk. This was consistent in all the dives modelled. This underlines the importance of early intervention with oxygen during first aid and resuscitation of diving accident victims.

Conclusion

This model demonstrates that in near-drowning:

1 there is an increased risk of decompression sickness;
2 the risk increases the longer the dive, particularly in square dive profiles;
3 this increased risk is reduced if oxygen is used early in resuscitation but may not decrease it below the USN chosen maximum risk of 2.3%;
4 recompression should be considered in all near-drowned divers;
5 a sudden decrease in cardiac output associated with hospital resuscitation (IPPV and PEEP) does not increase the already increased decompression sickness risk provided the patient's cardiac output was normal prior to resuscitation commencing;
6 in 18 m dives the risk does not change with a multi-level dive conducted in accordance with the DCIEM tables; and
7 all divers who are severely shocked at the initial presentation or who have been resuscitated from a cardiac arrest need recompression because the risk of DCS is between 25 and 58%. However, the optimal timing of recompression therapy has not been determined and will be the subject of a future study.

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LUNG ASSESSMENT FOR SUBMARINE ESCAPE TRAINING

Robyn Walker

Key Words

Escape, medicals, rescue, submarine, training.

Introduction

The successful completion of pressurised submarine escape training (PSET) is a pre-requisite for qualification as a submariner in the Royal Australian Navy (RAN). There are two principle methods of leaving a disabled submarine, escape and rescue. Escape is where the survivors leave the submarine through an escape hatch and make an ascent through the water to the surface. This escape may be from the escape tower (SET), where the submariner spends the least time exposed to ambient environmental pressure or from a flooded compartment that is in direct contact with the outside environment.[1] This is known as compartment escape and exposes the individual to the ambient environment for a greater period of time. It is possible to perform a SET escape from a depth of 180 msw and a compartment escape from a depth of 60 msw.

Rescue involves the use of a submersible to transport any survivors from a disabled submarine to the surface where decompression can be undertaken if required.[2,3] The depth of the submarine and the operating capability of the rescue craft generally limit rescue. As it can not be assumed that rescue will always be possible, the RAN requires all submariners to have demonstrated confidence in the escape procedure.

The RAN conducts PSET at HMAS STIRLING. The submarine escape tower is a purpose built column of water 22 m deep. Participants can enter the water at the surface or at various depths (through air locks) to practice different methods of escape. The environment is strictly controlled, the water temperature warm and the tower brightly lit. While this does not equate to the likely scenario of a disabled submarine, which may be cold and dark with a contaminated atmosphere, the training environment affords a higher level of safety.

Training methods

Escape training methods taught include buoyant ascents and hooded ascents. During buoyant ascents a buoyancy aid (inflated life jacket or submarine escape jerkin) is worn to assist the escaper to the surface and the escaper is required to perform a controlled exhalation all the way to avoid pulmonary over inflation. During buoyant ascents escapers can achieve ascent rates of between 92-120 metres per minute. During hooded ascents the escaper breathes normally from air retained in a hood worn over the head. The RAN uses a submarine escape immersion suit during hooded ascents and the escapers can reach an ascent rate of 150 metres per minute. These ascent rates are up to 15 times greater than those routinely practiced by recreational divers.

While hooded ascents are the preferred escape method a buoyant ascent may be required if the hood ruptures or leaks during the ascent and the escaper finds his head in water.

Escape tower

The escape towers in RAN submarines accommodate one person only. During an escape the pressure within the escape tower is equalised with the outside water which then allows the outer hatch to spring open. During the compression phase the ambient pressure within the tower accelerates exponentially, the pressure doubling every four seconds. To achieve the maximum escape depth of 180 metres, pressurisation of the escape tower takes less than 20 seconds. This short time under pressure reduces the risk of serious decompression illness.

Medical risks

Medical risks associated with PSET include pulmonary barotrauma, arterial gas embolism (AGE), middle ear, sinus and facial nerve barotrauma, decompression illness and drowning, albeit unlikely in this highly controlled environment.

A medical risk assessment of PSET conducted by Weathersby et al. revealed hooded ascents appear safest with an AGE incident rate of 0.1 – 0.6 per 1000 escapes with a fatality rate of 10 – 50 times lower.[4]

They also noted a trend of a higher incidence rate of AGE for each type of escape with increasing depth. Factors known to increase the risk of pulmonary barotrauma are buoyant ascents, novice trainees, increasing depth of ascent, increasing rate of ascent, some pre-existing lung diseases and small lung size in relation to body size. In one large study of SET accidents the incidence of pulmonary barotrauma among initial trainees was almost double that of requalifiers.[5] It is not intuitive to continue to breathe or exhale during an escape – it is a learned response.

It is also important to note that in a number of patients who have suffered pulmonary barotrauma with AGE, no predisposing factors have been identified. AGE has also occurred in individuals who have been observed to exhale normally during the ascent. There appears to be a substantially random component to the occurrence of pulmonary barotrauma and there is no completely safe training depth. PSET carries a real risk of morbidity and mortality.

In 109 cases of non-fatal pulmonary barotrauma associated with PSET, 104 cases suffered AGE and only 5 suffered pulmonary barotrauma without AGE (4 subcutaneous emphysema, 1 pneumothorax).[6] Of the 104 cases with AGE, 82 suffered AGE alone, 15 had AGE and mediastinal emphysema and 7 had AGE with pneumothorax.

Mechanism of Pulmonary Barotrauma

It is now thought that the over stretching of lung parenchyma causes the injury of pulmonary barotrauma by a transmural pressure change rather than a change in the volume of intrathoracic gas.[7] Experiments on positive pressure inflation of fresh human cadavers revealed that lungs expanding in an unsupported thorax burst at 70 mmHg, but if the lungs are confined they rupture in a different manner at pressures approximating 110 mmHg.[8] Some spontaneous pneumothoraces are associated with forced inspiratory manoeuvres such as hiccupping or the completion of functional tests of total lung capacity or peak inspiratory pressures.[7] In other words voluntary high inflations can stretch some parts of the lung beyond their elastic limits.

Ways of decreasing the risk of PSET

There are 3 possible ways of decreasing the risk associated with PSET:

a adequate training to decrease the likelihood of incidents associated with panic,

b slowing the rate of ascent, (however there are no practical means of achieving this), and

c medical screening to identify those with clinically detectable, pre-existing lung disease.

Training methods

As previously stated evidence suggests that hooded ascents carry less risk than buoyant ascents and there is a general trend to higher incident rates with deeper escape depths. Overall the frequency of incidents and the risk of injury is decreased by limiting the number and depths of ascents conducted. The RAN PSET program prior to 1995 included 2 buoyant ascents from 9 metres and 1 buoyant ascent from 22 m wearing the submarine escape jerkin, 1 hooded ascent (compartment escape) from 22 metres and 2 hooded ascents (escape tower) from 22 metres. After an extensive review in 1995 this program was amended to reduce the risk of injury to trainees. The program now comprises 2 buoyant ascents from 9 m wearing the submarine escape jerkin and 2 hooded ascents (escape tower) from 22 m.

Medical screening

To join the RAN submarine service all potential submariners must have successfully passed the RAN entry medical, be less than 35 years of age, have no history or evidence of pulmonary disease, no cysts, blebs or scarring and have a forced expiratory volume in one second/ forced expiratory capacity (FEV_1/FVC) of greater than 75%. They also require a normal inspiratory and expiratory full plate chest X-ray.

Age limit

Lung compliance describes the extent to which lungs expand for each unit increase in transpulmonary pressure. A fall in vital capacity and an increase in residual volume and functional residual capacity accompany aging.[9] These changes can be accounted for almost entirely by the changes in lung elasticity with reduced elastic recoil in the older patient. Mitman concluded that with increasing age there is a decrease in chest wall and total lung compliance and the associated increase in residual volume limits the extent to which you can exhale.[9] He also noted that the biggest reduction in lung compliance occurred in the 30 – 39 year age group.

Colebatch et al. have shown that individuals with small stiff lungs are more liable to lung rupture.[10] It is also known that as the lung reaches total lung capacity, compliance decreases, and in the setting of pulmonary over inflation is more likely to rupture. Lung compliance measurement is not simple and requires invasive techniques that can also be expensive. It has also been demonstrated that compliance measurements by themselves are inadequate as an index of pulmonary barotrauma susceptibility because they may not detect regional variations in lung compliance. For this reason the measurement of compliance is not recommended as a screening test and the RAN has therefore decided to use 35 years as the maximum age permitted for initial PSET.

Spirometry

In 1975 spirometry was introduced as a measure of respiratory fitness in the screening of Royal Navy (RN) divers and submariners. Clinical opinion in the RN was that, dependent upon age, a FEV_1/FVC of less than 75%

suggested abnormal lung function and further investigation was warranted prior to declaring the individual fit for diving or PSET. However, the predictive value of spirometry as an indicator of risk for PBT had never been established.

Brooks et al. reviewed the data from the Institute of Naval Medicine as a step towards validating the use of spirometry as a screening tool.[11] They included all Caucasian submariners and submariner candidates who had presented for screening between late 1983 and mid 1986. All had passed the RN medical and submarine medical examination and smoking history was accounted for. A major advantage of this study was the consistency of data collection from using the American Thoracic Society standards for spirometry. The study compared lung function variables for predictive value for pulmonary barotrauma. No association was found for the FEV_1/FVC ratio, however, a highly significant association for PBT risk was found for a low FVC. They concluded that up to 25% of submarine escape and perhaps diving accident cases involving PBT could be prevented by making those with an abnormally low FVC (less than 2 standard deviations below normal) medically unfit. However, the exclusion rate by this criteria would be far less than that of the FEV_1/FVC ratio currently in use.

The RAN uses spirometry as a screening tool for the presence of obstructive disease and prompts the requirement to discuss the results with an experienced underwater medicine clinician. A low FVC will also be detected and such candidates will be scrutinised carefully. Spirometry should be avoided on the morning of PSET to minimise the risk of a spontaneous pneumothorax.

Chest X-ray

Scarring within the lung has been associated with an increased risk of PBT, however, the site of injury may be inconsistently related to the scar.[7] Pleural scarring may predispose for PBT but the magnitude of this risk is uncertain. A chest X-ray may also detect clinically asymptomatic cysts, blebs or bullous areas. Full plate inspiratory and expiratory films are taken as it is considered that expiratory films enhance the detection of fibrosis or bullous lesions.

Daily Review

All candidates are questioned each morning of PSET for symptoms of cough, upper respiratory tract infection, malaise etc. Any positive response requires clearance by the Medical Officer prior to the start of training.

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LOSS OF CONSCIOUSNESS IN DIVERS

James Francis

Key words

Diving industry, equipment, occupational diving, physiology, recreational diving, unconsciousness.

Abstract

Loss of consciousness while a diver is in the water is potentially a pre-morbid condition as it can rapidly progress to drowning. There are many causes of loss of consciousness and in this brief review only the main ones are dealt with. In attempting to determine the cause, consideration should be given to the type of breathing equipment being used and the phase of the dive in which loss of consciousness occurred. In addition to the diving-related causes of loss of consciousness, it should be remembered that divers are vulnerable to trauma and the medical conditions to which the general population is susceptible.

Introduction

In this presentation, I am not going to discuss the management of an unconscious diver. I am going to assume that care has been taken to manage the diver's airway, breathing and circulation, a primary survey has been conducted and the emergency services have been contacted. Instead, I will focus on determining the cause of the loss of consciousness (LOC) and, in doing so, point out that it can be a demanding task.

If a history is available from a diving partner, dive supervisor or other witness, it is important to determine at what point in the dive the loss of consciousness occurred and whether or not there were any prodromal symptoms or signs.

Take note of what equipment the diver was using, what the purpose of the dive was and the surface and underwater conditions. Does the diver have any relevant past medical history? How experienced is the diver?

The more information that is obtained, the more likely it is that the cause will be determined. Although I will focus on diving-related causes of LOC, it should be remembered that divers are vulnerable to the medical conditions that cause LOC in the general population, in particular cerebrovascular accidents and myocardial infarction can and do happen when people take to the water.

In the following sections I will discuss the importance of the underwater breathing apparatus (UBA) being used, the phase of the dive and the environmental conditions that are relevant to LOC. After that I will briefly discuss each of the main diving-related causes of loss of consciousness.

Breathing apparatus used by the diver

There are advantages and disadvantages in the use of most types of breathing apparatus. For example, one of the earliest and longest used rigs, the surface-supplied, free-flow hard-hat has intrinsic flaws.[1] Adequate levels of air flow to early designs of helmet generated noise levels that impeded communication and, with repeated use, caused hearing loss in the diver. A level of air flow that resulted in acceptable noise levels was inadequate to control the level of CO_2 in the helmet and hypercapnia was a problem, particularly when the diver was working hard. To some extent, these problems have persisted with subsequent designs. Every set has potential problems that may result in LOC. Users of scuba sets rely on it being charged with clean air, divers with constant PO_2 re-breathers rely on the accuracy of their oxygen sensors and the integrity of their battery and CO_2 scrubber. Should any of these fail, LOC is a possible consequence. Table 1 shows various types of diving rig and their propensity for generating the conditions that can result in LOC.[2]

Phase of dive

Knowing when the diver lost consciousness provides a powerful clue as to the likely cause. For example, it is impossible for decompression illness (DCI) to cause LOC during the descent or bottom phases of a dive. Equally, nitrogen narcosis will not cause LOC early in the descent or late in the ascent phases of a dive. Table 2 lists the causes of LOC by phase of a dive. Since these are, in some cases, dependent on the equipment being used, I have annotated this accordingly.

Causes of loss of consciousness

HYPOXIA

Diving is normally a hyperoxic process and so scuba diving with air should not result in hypoxia unless the regulator fails completely or the diver runs out of air. Both situations can result in asphyxia although, in the latter situation, there is usually enough air in the cylinder to get the diver to the surface. If a closed circuit rig is used, hypoxia can occur if there is a failure of the oxygen sensors or the injector circuit. Most modern sets have a display to alert the diver to a low oxygen situation and a manual override can be used to restore the partial pressure of oxygen. Depending on the design of the rig, a battery flood may disable some of the safety features making hypoxia more likely. Although hypoxia on the bottom is possible, it becomes more likely during ascent when the partial pressure of oxygen in the counterlung is falling. In semi-closed sets, failure of the injectors may also cause hypoxia on the bottom. As with closed circuit sets, it is on ascent that hypoxia may become a problem, especially if the diver is working hard.

Military divers using a 100% oxygen closed-circuit rebreather may experience so-called "dilution" hypoxia. Unless the set is purged properly, the counterlung may gradually come to contain an excessive amount of nitrogen originating from the lungs and body tissues as the diver "off gases" into the set. As with other closed circuit sets, this problem is most likely to become manifest during ascent.

The scuba diver with regulator failure will experience both hypoxia and hypercapnia and the symptoms of the latter will predominate. The onset of pure hypoxia can be subtle and go unnoticed by the diver until he or she is in potentially serious trouble. The symptoms include: impaired judgement, disorientation in time and space, euphoria, excitement and headache. Dyspnoea, which is such a marked consequence of hypercapnia, is a late symptom in hypoxia and may not be noticed before the diver experiences loss of consciousness.

CNS OXYGEN TOXICITY

This is never a problem with normal air diving. It can become so when mixed gases or pure oxygen are used. With the increasing popularity of mixed gas diving among the sport diving community, oxygen toxicity is becoming a significant hazard. The likelihood of CNS oxygen toxicity increases with the partial pressure of oxygen breathed and the duration of exposure, usually a P_iO_2 of about 2 ATA or higher is needed.[3] There are considerable variations in sensitivity to oxygen toxicity between individuals and within an individual from day to day.[4,5] Furthermore, factors such as immersion in thermoneurtal, hot or cold water, exercise, and hypercapnia exacerbate the toxicity of oxygen on the brain.[6-9] Thus, while there are ways of predicting the effect of hyperbaric oxygen on the lung by using, for example, the unit of pulmonary toxic dose (UPTD), this is not possible for the effect of oxygen on the brain.

Even when very high partial pressures of oxygen are breathed there is a latent interval of a few minutes before the onset of CNS oxygen toxicity. Equally, oxygen toxicity may be expressed for a few minutes after the partial pressure of oxygen is reduced. This is the so-called "off effect".[8] The most dangerous aspect of CNS oxygen toxicity, from a diver's perspective, is that it can be expressed as a grand mal seizure without warning. Solo divers, and particularly those who are using a mouthpiece rather than a full face

TABLE 1

CAUSES OF LOSS OF CONSCIOUSNESS IN DIVERS USING VARIOUS DIVING SETS

UBA	Gas	Hypoxia	CNS O_2 Toxicity	Hypercapnia	Nitrogen Narcosis	Contaminated Gas	DCI
Demand scuba	(air)	0	0	+	+	+	+
	(N_2-O_2)*	0	+	+	+	+	+
Surface-supplied demand helmet	(air)	0	0	0	++	++	+
	(N_2-O_2)*	0	++	0	+	+	++
	(He-O_2)†	0	++	0	0	0	++
Free-flow helmet	(air)	+	0	+++	++	++	++
Closed scuba	(100% O_2)	+	+++	++	0	0	0
Semi-closed scuba	(N_2-O_2)*	++	++	++	+	0	+
	(He-O_2)†	++	++	++	0	0	++
Constant PO_2 scuba	(N_2-O_2)§	+++	+	++	++	0	++
	(He-O_2)§	+++	+	++	0	0	++

NOTES

*32.5% O_2 (to 40 msw) †16% O_2 (to 90 msw) § pO_2 0.7-1.4 ATA

0 = improbable + = possible ++ = probable +++ = very probable

Adapted from Flynn ET. Medical supervision of diving operations. In *Diving Medicine 3rd Ed.* Bove AA Ed. Philadelphia: WB Saunders, 1997; 323.

mask, run a high risk of losing their gas supply irretrievably either during or following the clonic phase of the seizure. Fortunately, there may be warning signs of impending CNS oxygen toxicity as shown in Table 3.[10] Mixed gas divers who experience any of the listed symptoms while at depth should take action to reduce their P_iO_2 by switching breathing mix or reducing their depth.

HYPERCAPNIA

Hypercapnia is not only potentially hazardous itself, it also potentiates the effects of nitrogen narcosis and oxygen toxicity. In the diving environment, a certain degree of hypercapnia is common and may arise because of the qualities of the UBA being used (increased breathing

TABLE 2

CAUSES OF LOSS OF CONSCIOUSNESS IN DIVERS BY PHASE OF THE DIVE

	PRE-DIVE	DESCENT	BOTTOM	ASCENT	POST-DIVE
Hypoxia	May occur using semi-closed set with hypoxic mix	Unlikely	Possible using closed set or 'out of air'	Most likely time using closed or semi-closed set	Should not happen de novo
CNS oxygen toxicity	Impossible	Possible	Possible	Unlikely but may occur *	Unlikely but may occur*
Hypercapnia	Should not happen de novo	Possible scrubber failure using closed or semi-closed set	Most likely time Faulty scuba regulator Using hard hat Scrubber failure using closed or semi-closed set	Unlikely PCO_2 will fall during ascent	Should not happen de novo
Carbon monoxide	Should not happen de novo	Unlikely	Possible	Most likely time	Unlikely
Nitrogen narcosis	Impossible	Possible air and nitrox mixes only	Most likely time air and nitrox mixes only	Unlikely	Impossible
DCI	Impossible	Impossible	Impossible	Possible using any UBA	Most likely time
Near drowning	Impossible	Possible	Possible	Possible	Possible delayed onset of symptoms/signs
Trauma	Possible	Possible	Possible	Possible	Possible
Hypothermia	Should not happen in temperate or warmer climates	Unlikely	Possible	Possible	Should not happen in temperate or warmer climates

NOTES
* = "off phenomenon"

resistance and/or dead space), the effect of depth (increased breathing gas density), the diver himself (skip breathing and/ or the suppression of ventilatory drive by a high P_iO_2) or, in those using rebreathers, failure of the CO_2 scrubber.

Inadequate ventilation of hard hats was a common cause of hypercapnia in older designs. Hard work greatly increases the risk of hypercapnia.

As with oxygen toxicity, there is great inter-individual variability in susceptibility to CO_2.[11] In most people, the onset of CO_2 toxicity is heralded by dyspnoea, anxiety and headache. This may progress to include disorientation, mental impairment loss of consciousness and convulsions. In those who are tolerant of hypercapnia, the first sign may be loss of consciousness or a grand mal seizure.

CONTAMINATED GAS

A poorly maintained compressor, or one that is sited with its intake down wind of its own exhaust or another source of pollution is a potential cause of divers breathing contaminated gas underwater. This may occur in those who charge their cylinders from the contaminated source or who receive a surface supply from it. Another potential source of pollution is solvents used to clean diving apparatus if this is done improperly. Although these sources can introduce a number of different hydrocarbons into a diver's breathing gas, it is carbon monoxide that is the most important contaminant. This is a problem with compressed air rather than mixed gas diving. Commercial mixed gases are usually made up from pure sources.

Carbon monoxide is a metabolic poison competing with oxygen for binding sites on haemoglobin and other haem-containing proteins for which it has a far higher affinity. During descent, the partial pressures of both CO and O_2 increase and, even in the presence of quite severe contamination, the diver may be unaware of this because, with increasing depth, more oxygen can be carried in plasma. Thus it is during decompression, as the partial pressure of oxygen falls, that symptoms most commonly become manifest. The symptoms include nausea, headache, visual disturbance, weakness, disorientation, convulsions and, eventually, loss of consciousness. Measurement of the carboxyhaemoglobin level will confirm the diagnosis, but the recorded level is a poor index of the severity of poisoning.[12]

TABLE 3

SYMPTOMS AND SIGNS OF CNS OXYGEN TOXICITY

Facial pallor
Sweating
Bradycardia
Choking sensation
Sleepiness
Depression
Euphoria
Apprehension
Changes of behaviour
- Fidgeting
- Disinterest
- Clumsiness

Visual symptoms
- Loss of acuity
- Dazzle
- Lateral movement
- Decrease of intensity
- Constricted visual field

Acoustic symptoms
- Music
- Bell ringing
- Knocking

Unpleasant olfactory sensations
Unpleasant gustatory sensations
Respiratory changes
- Panting
- Grunting
- Hiccoughs
- Inspiratory predominance
- Diaphragmatic spasms

Severe nausea
Spasmodic vomiting
Vertigo
Fibrillation of lips
Twitching of lips
Twitching of the cheek and nose
Palpitations
Epigastric tensions
Syncope
Convulsions

From: Clark JM. Oxygen toxicity. In *The Physiology and Medicine of Diving. 4th Edition*. Bennett PB and Elliott DH. Eds. London: WB Saunders Co., 1993; 135.

NITROGEN NARCOSIS

Nitrogen narcosis becomes noticeable in most divers breathing air at a depth of about 30 m. The effect is very similar to intoxication with alcohol, with a similar impact on performance. The decree of intoxication is progressive with depth such that below 70 m it is severely incapacitating. As with alcohol, the effect can be ameliorated with regular exposure and some people appear to be more tolerant of the effect than others. A rapid descent generates a greater narcotic effect than a slow one and the effect is rapidly reversed by surfacing. There is no hangover. Nitrogen narcosis does not normally result directly in loss of consciousness. It is more likely to occur because the narcosed diver does something that they normally would not. This includes loss of buoyancy control followed by an uncontrolled ascent and failure to keep track of time or tank contents so that they run out of air. Loss of consciousness may follow as a result of near drowning or DCI that had its origins in narcosis.

DECOMPRESSION ILLNESS

Loss of consciousness can arise from classical arterial gas embolism, cerebral decompression sickness or from severe cardiopulmonary involvement. The latter is very rare and results in LOC late and, if untreated, as a pre-terminal event. More commonly, loss of consciousness is an early sign of DCI. The natural history is for spontaneous recovery rather than progression.[13]

TRAUMA

Head injury is a hazard for divers who surface rapidly under a boat or pontoon. The other main traumatic cause of LOC is a laceration or puncture wound with sufficient bleeding to cause shock. Although such injuries can be caused by large fish, this is rare and it is worth remembering that man is the most dangerous animal in the water and on it. Unshrouded propellers can cause extensive injury.

HYPOTHERMIA

I spoke at some length on hypothermia at the 1997 SPUMS meeting in the Bay of Islands.[14] By definition, a diver has to be severely hypothermic to lose consciousness which means a core temperature of 27°C or below. Moderate hypothermia (core temperature 31-28°C) can result in a semi-conscious state and cause the victim to drown.

NEAR-DROWNING

I will not discuss near drowning in any detail because it will be covered later in the meeting.

I will just observe that in addition to being a potent cause of LOC in its own right, it can also be the outcome of any of problems discussed above that cause loss of consciousness.

The undersea environment is hostile to man and potentially lethal to one who is unconscious. While the cause of death in many divers who are retrieved from the water is deemed to have been drowning, there is often a reason why this happened.

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THE ANATOMY OF DEATH IN TWO DIVERS

Chris Acott

Key Words

Case report, cerebral arterial gas embolism, deaths, drowning, pulmonary barotrauma.

Introduction

Between New Year's Day and this conference in May 2001, two divers have died in South Australia. We have a well informed Coroner in South Australia who insists that in any deaths involving divers, either I or a doctor from the Hyperbaric Unit, attends the post-mortem and directs the pathologist on what to look for.

It usually assumed, and has been for many years, that novice divers probably die of cerebral arterial gas emboli (CAGE) following panic or distraction causing breath holding during ascent. More experienced divers die of many other things as well as CAGE due to pulmonary barotrauma. Some divers develop CAGE from bubbles passing through a patent foramen ovale after a fairly strenuous dive.

What to do at a diving death

In any diving death it is necessary to make sure that the equipment is impounded. After the remaining air pressure has been be recorded, the cylinder(s) should be turned off and the number of turns required recorded. Nobody at the scene should touch the equipment after that because it will be needed for analysis and checking for function later. If possible, photograph the body as it is brought out of the water or lying on the beach. Photograph the body with the equipment on. I know it sounds very morbid but it is amazing what you can find out from a photograph. It is important to photograph each individual piece of equipment, particularly the contents gauge to register how much air was in the cylinder(s) at the end of the dive. The most important thing is to make sure nobody interferes with the equipment.

Confusing factors

One of the problems with diving deaths is that you may actually get wrong information about divers or the dive even from a relative. One really has to follow up and find out exactly what went wrong.

Case 1

THE INCIDENT

This unfortunate 45 year old female diver surfaced and signalled to the boat. However there was no response to the boat's return signal and the diver was seen to submerge. The dive master surfaced and was pointed to where the diver had submerged, swam over and found the diver in about 5 m with the regulator out of her mouth. The regulator was not replaced during the rescue and the ascent to the surface. When the diver was hauled into the dive boat they were unable to resuscitate her. There was a doctor and nurse on board, so it is likely that the resuscitation attempts were quite good. She was pronounced dead at the local hospital. I was contacted soon after that by the local police. I told the them to impound the diver's equipment. There was between 50 to 80 bar still left in the cylinder.

I contacted the local hospital, spoke to the duty GP and asked him to organise a chest X-ray of the body supine and sitting if at all possible. That sounds very morbid but one is looking at a sudden, unexpected death and it is important to see if there is air in the heart. If people object to sitting the body up, it can be rolled onto a side which may show fluid levels in the heart.

THE ORIGINAL HISTORY

The dive was to 18 to 20 m for about 25 minutes, so a lot more air was used than one would expect, to leave only about 50 to 80 bar in the cylinder. The buoyancy compensation device (BCD) was uninflated, there was no evidence of rapid ascent precipitated by the BCD. There were no apparent problems during the drive other than separation during the dive and the diver appeared fairly comfortable. She was supposed to be an experienced cave diver. She was supposed to have had a recent diving medical. Her son thought she was doing a refresher course in diving. She had a recent hospitalisation for a laparoscopic appendicectomy and the son thought that she had no medical problems before this.

BEFORE THE POST-MORTEM

I thought cerebral aterial gas embolism was probably unlikely. She was an experienced cave diver so should have good buoyancy control. I thought that it might be a sudden death from a myocardial infarction, sub-arachnoid haemorrhage or intra-cerebral bleed. The X-rays showed massive pulmonary oedema.

THE POST-MORTEM

She was a fairly large lady, who had bitten her tongue on her right side. She had marks on her chest consistent with CPR. I checked her ears for signs of ear barotrauma as even a Valsalva during the ascent to try and clear the ears can precipitate pulmonary barotrauma and CAGE. There was no sign of any cerebral vascular event.

When the chest cavity was opened we found there were pleural adhesions in the right middle lobe and right lower lobe. She did not have a patent foramen ovale. There was vomit in the trachea. There was no sign of a recent myocardial infarction and the pathologist said, “Oh, the lady drowned”. There was no air seen in the heart. No pneumothorax or mediastinal gas of any description was present.

But why did she drown? That is what we wanted to know.

CAUSE OF DEATH

Looking at the unexpected findings, the bitten tongue and the pleural adhesions I postulated the cause of death was CAGE. I thought that the bitten tongue was consistent with a convulsion underwater, otherwise why would her tongue have been bitten? The pleural adhesions had caused a local change in lung compliance and hence she ended up with pulmonary barotrauma and gas embolism.

LATER HISTORY

Later it came out that her son had got everything completely wrong. She was not an experienced diver. In fact this was only her 8th ever dive. I have no idea where he got the information that his mother was a cave diver. This was her first dive following a laparoscopic appendicectomy which was performed at the Flinders Medical Centre. Her medical history from the Flinders Medical Centre said that she was an asthmatic. She had suffered a pneumothorax in about 1996. She had had frequent chest infections throughout her life as well as frequent bouts of abdominal pain from endometriosis. The pathologist’s report of the appendix removed laparoscopically was that the appendix was normal and the pain was probably another bout of endometriosis. The chest X-ray done on her in 1997 showed an ill defined increase in density in the right middle zone. It showed definite focal consolidation in the lateral films, however there was an area of increased capacity anteriorly, probably a pleural thickening and a parietal lesion, which is what we found in the post-mortem.

Her diving medical was quite interesting. She answered “No” to chest problems in the past but there was a question mark by this question, and who put that there is yet to be determined, and probably will be determined in the Coroner’s Court. The diving medical was performed by a general practitioner in Adelaide. He is not known to me and I think I probably know everybody in Adelaide who has the proper training and does diving medicals.

Case 2
THE INCIDENT

A month later a diver surfaced with his buddy and then died on the surface.

THE ORIGINAL HISTORY

Again he was reported as being an experienced diver. He was known to be on anti-hypertensive treatment and the death was recorded in the paper as being from a heart attack on the surface. The ascent was controlled. He died on the surface.

The dive was fairly innocuous. It was the second dive of the day using fresh cylinders. Two or three hours earlier they had done a similar dive. The dive team consisted of the victim, the victim’s wife and a friend who was leading the dive. After 20 minutes at 10 m the victim had 50 bar in his cylinder. The others had between 100 and 150 bar. The friend and the victim ascended leaving the wife on the bottom. The victim was told to inflate his BCD and float while his friend went down to bring his wife to the surface because they were both very novice divers. He was alright on the surface. He spoke to his friend. The friend then descended, collected the wife at 10 m and brought her to the surface. This did not take long. When they returned to the surface the friend noticed that the victim was floating or sunning himself on his back. When he called out to him to come back to the boat there was no reply. So the friend swam over to the victim and found his buoyancy jacket was over inflated. The victim was unresponsive and he had vomit dripping from the side of his mouth. The friend did not know whether he was breathing or not. Resuscitation was unsuccessful.

BEFORE THE POST-MORTEM

I was able to get a chest X-ray done but it was not done in the sitting position but on the side. The victim was very overweight and that was one of the reasons why they could not sit him up. He was huge. There was no pneumothorax on the chest X-ray. There were fluid levels and air in the heart.

POST-MORTEM

Inspection of his mouth showed that he also had bitten his tongue on the right side, just like the other diver. There were pleural adhesions in his left upper chest. His coronary arteries, surprising enough, were clear. The pathologist said “one could drive a truck through them, so we are probably not dealing with a heart attack”. There was no evidence of a cerebral vascular event. However there was air in the heart.

CAUSE OF DEATH

There is no doubt in my mind that this man died from an embolic event, CAGE, leading to drowning.

LATER HISTORY

It turned out that this man had never had a diving medical. He was on anti-hypertensive treatment. He also had multiple medical problems with irritable bowel and back problems. In 1997 he had a motor vehicle accident where he had blunt chest trauma to his left upper chest, which is where the adhesions were found, but the chest X-ray done straight after the accident was negative.

Similarities between the two cases

There are striking similarities between the two cases, both were novice divers but reported as being very experienced. Both were obese. Both had multiple medical problems. Both were sudden deaths on the surface of the sea from gas embolism. Both were initially thought to be a myocardial event but there was no cerebral vascular event or coronary artery disease found in either one. Both had bitten their tongues which to me indicates that both had had a convulsion. Both had pleural adhesions. They were both diving in a team, they probably had controlled ascents. Their dive medicals were probably inadequate and none.

Both were alone on the surface but I do not think that a buddy would have been any use at any stage during the rescue. Except perhaps they would have been able to tell us what really happened.

They were both recorded by the pathologist as being drowning deaths and on the second one the pathologist, even after we found air in the heart, said "I'll still put this down as a drowning death for insurance purposes". In this man I think his convulsion occurred when he went to inflate his buoyancy jacket. He was floating when he started to convulse and that is why his jacket over-inflated.

Conclusions

These two divers died from drowning, but the cause of the drowning was air embolism, causing unconsciousness, after barotrauma in lungs tethered by pleural adhesions.

It is very important that an experienced diving doctor, with good reasoning abilities attends, every post-mortem after a diving death to integrate such oddities as bitten tongues into the pathologist's diagnosis.

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EFFECT OF HYPERBARIC OXYGEN THERAPY ON LUNG VOLUMES IN NORMAL SUBJECTS AND HEAVY SMOKERS.

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Key Words

Hyperbaric oxygen, physiology, research, lung volume, airway obstruction

Abstract

Decompression from hyperbaric conditions may be associated with air-trapping if the alveoli are unable to empty rapidly enough as ambient pressure decreases. In particular, such air-trapping may occur with the airway obstruction seen in emphysema and asthma. To determine whether this is clinically detectable, subjects with a heavy smoking history and airway obstruction were studied in a hyperbaric chamber.

Fifteen subjects underwent lung volume estimation by body plethysmography at sea level and again immediately after hyperbaric oxygen therapy at 240 kPa for 90 mins. Results were compared with those of seven non-smokers undergoing the same treatment, and five non-smoking staff breathing air.

There were no significant changes in lung volumes in any of the study groups in terms of their lung volumes. The smokers had more airway obstruction than the other groups, but this was mild despite a heavy smoking history. Mild airway obstruction does not appear to be associated with significant gas-trapping after hyperbaric therapy.

Introduction

Patients receive hyperbaric oxygen therapy (HBO_2T) for a variety of medical indications, including osteoradionecrosis, necrotising infections and chronic ulcers secondary to diabetes and vascular insufficiency. An increasing number are elderly and have vascular insufficiency, or have a history of head and neck squamous cell carcinoma secondary to smoking. These smokers or ex-smokers may benefit from HBO_2T, but there are theoretical reasons why acute changes in lung volumes might occur in some subjects with airway dysfunction. Such dysfunction has not been documented, nor have adverse events been reported. It remains possible, however, that airway obstruction in smokers or asthmatic subjects might cause trapping of gas within the lungs as alveolar gas expands on decompression.

It was hypothesised that those with airway obstruction secondary to smoking would have a tendency to trap air within their lungs during decompression, leaving them with an increased residual volume immediately after the treatment. The data from the limited number of studies that are available suggest that some changes take place during HBO_2T, although these studies were designed to look at chronic effects of these conditions. Thorsen et al. showed a small reduction in expiratory flow and diffusion with HBO_2T (240 kPa 90 min daily for 21 days) in 20 subjects.[1] Clark et al., studying normal volunteers in a range of pressures up to 300 kPa, showed a slight fall in spirometry and diffusion capacity in 8 of 15 subjects over 5-18 hours.[2] These changes are thought to represent the effects of oxygen toxicity upon the lung.[3] Fractionating oxygen exposure appears to reduce the risk of toxicity.[2,4] On the other hand, Pott et al. were unable to demonstrate significant changes in spirometry, lung volumes, or carbon monoxide diffusing capacity in 18 subjects treated by HBO_2T (240 kPa 90 min daily for 42 days), suggesting that the effects are not large.[5]

One aspect that has not been addressed specifically by the above studies is whether small airway obstruction could cause acute gas-trapping during decompression. If gas-trapping due to small airway obstruction occurs during decompression, there could conceivably be hyper-inflation of the obstructed lung units and an increased risk of pulmonary overpressure injury. This is one of the reasons why subjects with active asthma are advised not to dive. There are, however, no data to suggest that those who have asthma and who dive have a higher incidence of pulmonary barotrauma from this mechanism. It was hypothesised that HBO_2T in those with a heavy smoking history and evidence of pre-existing gas-trapping with small airway obstruction would show an increase in residual volume after HBO_2T. Gas trapped during HBO_2T would expand on decompression due to Boyle's Law but be unable to escape from the lungs because of small airway obstruction.

Methods

The study was approved by the hospital ethics committee and informed consent was obtained. Patients currently smoking and receiving HBO_2T underwent plethysmographic evaluation of lung volumes before and after a single HBO_2T session. These results were compared with a control group of both non-smoking patients undergoing HBO_2T and staff members who were compressed in the chamber breathing air. Participants included 15 smokers (>40 pack year exposure), 7 control subjects (non-smokers or 'light' ex-smokers, <10 pack years), and 5 non-smoking staff members who attended patients during treatment.

HBO_2 treatment

All subjects and staff had been passed as 'fit to dive' according to current standards.[6] The chamber was pressurised to 240 kPa (equivalent to the pressure at 14 m of sea water) for 90 minutes, followed by a 20 minute decompression to 101 kPa (a routine profile frequently utilised at this facility).[7] Patients breathed 100% oxygen via a face mask throughout the procedure, while staff were breathing air during the 240 Pa period and 100% oxygen during decompression only.

Body plethysmography and spirometry

Pulmonary function tests were measured using body plethysmography (Fennyves & Gutz, Basle, Switzerland) according to published methods.[8] The following values were derived: forced expiratory volume in the first second (FEV_1), maximal mid-expiratory flow (MMEF), forced vital

TABLE 1

SUBJECT CHARACTERISTICS, REASONS FOR HYPERBARIC OXYGEN TREATMENT, AND BASELINE LUNG FUNCTION (SE).

	Age (range)	**HBO_2T indication**	**FEV (L)** *% predicted*	**%FVC**	**FVC (L)** *% predicted*	**TLC (L)** *%predicted*
15 Heavy smokers	61.0	Soft tissue osteoradionecrosis: 8	2.82	79.28	3.55	6.28
	(33-81)	Retinal vein thrombosis: 3	(0.23)	(1.79)	(0.15)	(0.25)
		One each of: radiation myelitis,				
		xerostomia, non-healing wound,	*100.8*		*90.8*	*97.6*
		and Crohn's abscess.	*(8.9)*		*(8.0)*	*(7.9)*
7 Light or non-smokers	40.5	Soft tissue osteoradionecrosis: 4	3.53	84.34	4.19	6.12
5 Staff (non-smokers)	(25-71)	One each of:	(0.01)	(0.98)	(0.17)	(0.32)
		retinal vein thrombosis,				
		optic neuropathy,	*108.2*		*99.51*	*95.8*
		and diabetic ulcer.	*(14.0)*		*(10.2)*	*(8.8)*

TABLE 2

COMPARISON OF LUNG FUNCTION BEFORE AND AFTER HYPERBARIC OXYGEN THERAPY (90 MINS 100% OXYGEN AT 240 KPA), IN THOSE WHO HAVE A >40 PACK YEAR SMOKING HISTORY WITH THOSE WHO HAVE <10 PACK YEAR SMOKING HISTORY. COMPARISON OF % CHANGE IN HEAVY SMOKERS VERSUS CONTROLS USING UNPAIRED T-TESTS.

Lung volumes (% change)	Smokers (n=15)	Non-smokers (n=12)	p value
Total lung capacity % [se]	**-1.37** [0.72]	**-1.63** [0.87]	0.42
Pre v post (litres)	6.28 (0.25) v 6.20 (0.25]	6.12 (0.32) v 6.02 (0.24)	
Vital Capacity % [se]	**1.00** [1.94]	**0.95** [0.61]	0.64
Pre v post (litres)	3.55 (0.15) v 3.57 (0.17)	4.19 (0.17) v 4.21 (0.17)	
FRC % [se]	**0.00** [0.64]	**1.93** [2.25]	0.28
Pre v post (litres)	3.77 (0.24) v.3.77 (0.23)	3.22 (0.24) v 3.28 (0.22)	
FEV_1 % [se]	**0.48** [1.16]	**-1.61** [1.2]	0.04
Pre v post (litres)	2.82 (0.23) v 2.83 (0.22)	3.53 (0.01) v 3.47 (0.1)	

capacity (FVC), total lung capacity (TLC) and hence residual volume (RV).

Analysis

Results are expressed as mean percent change from baseline. Smokers >40 pack years were compared with those with non- and ex-smokers<10 pack years (including the staff members). Differences were analysed by unpaired t-tests between groups.

Results

Subject characteristics are summarised in Table 1. There were no differences in terms of predicted lung function, between non-smoking staff members, who breathed air, and the patients classified as non- or 'light' smokers, therefore all analyses are reported with staff members in the non- or 'light' smokers group.

The smokers tended to be older than the control group, and had a male preponderance (M:F 10:5, versus control group 6:6). Although the differences between the groups were small, these were significant in terms of FEV_1, FVC and RV (Table 1), when expressed as percent predicted, thus controlling for differences in age and sex between groups.

Thus, the smoking group had a lower percent predicted FEV1, FVC and increased RV compared to the control group, consistent with a mild smoking-induced airway obstruction and gas-trapping. MMEF was not significantly different between the two groups.

Lung function before and after HBO_2

Lung volumes measured as total lung capacity (TLC), functional residual capacity (FRC) and vital capacity (VC) did not change significantly, either between measurements or between the two groups (Table 2). There was a slight decrement in FEV_1 in normal subjects.

Discussion

There were no significant differences between the groups of subjects, except for very small changes in FEV_1. Smokers showed a small improvement in FEV_1, while the other subjects showed a small decrease. These changes were not sufficient to be clinically meaningful.

There was no evidence that additional gas retention occurred in heavy smokers, and no difference was observed between heavy smokers and either control subjects having HBO_2T, or control subjects who were breathing air under conditions of increased pressure. This suggests that gas-trapping either does not occur, or is very transient, under these conditions in these subjects. One criticism of this study might be that only 15 heavy smokers were studied, however the changes in TLC showed a decrease in lung volumes rather than the postulated increase. As this is in the reverse direction of the hypothesised change, a power calculation would not be able to indicate a sample size that would show such an effect.

It is conceivable that trapped oxygen diffused rapidly out of bullae and poorly ventilated air spaces, and had dissipated before the lung tests were performed, or that our smokers did not have a sufficiently severe degree of small airway obstruction. Lung volumes were estimated and completed within 15 mins of exit from the chamber, suggesting that gas trapping would have to be very transient if it did occur. Extrapolating from the rate of decrease of air in pneumothoraces, which is estimated to be 1-2 % per day,[9] it would seem unlikely that this study would have missed an important degree of gas trapping, even though the rate of diffusion of oxygen from the lung to the blood stream is estimated to be approximately twice that of nitrogen.[10] No studies have been performed that would allow us to estimate the rate of oxygen uptake from emphysematous bullae.

These data do, however, suggest that some residual gas should have been present in the lungs of these subjects if gas-trapping was significant. While it is true that the smokers were not severely obstructed in terms of their spirometry, it would be difficult to study those most severely affected as they would not usually be considered for HBO_2T, unless the indication for this treatment was particularly pressing.

From these results, we conclude that heavy smoking in association with mild obstruction does not increase the risk of gas trapping while breathing hyperbaric oxygen, and there does not appear to be any appreciable risks of HBO_2T in this regard. It is possible that mild asthmatic subjects with a similar degree of airway obstruction might not show any gas-trapping under hyperbaric conditions either, but such subjects were not involved in this study.

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ARTICLES OF INTEREST REPRINTED FROM OTHER JOURNALS

OCULAR TEAR FILM BUBBLE COUNTS AFTER RECREATIONAL COMPRESSED AIR DIVING

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Key Words

Air, bubbles, decompression, eyes, recreational diving, research.

Abstract

Previous authors have demonstrated an increase in tear film bubble counts following dry, compressed air dives. We examined the lower tear film meniscus for the presence of bubbles in 42 divers after compressed air dives on a single day and in 11 divers undergoing repetitive, multi-day diving exposures over 5 days. Following diving, bubble counts increased significantly ($P < 0.01$) from pre-dive values. From a pre-dive median (inter-quartile range) of 0 (0-0.33) bubbles/eye, single day divers reached a maximum bubble count at 48 hours after diving of 1 (0-2.25) bubbles/eye. Similarly, from a pre-dive count of 0.33 (0-1) bubbles/eye, multi-day divers had increased bubble counts from 24 hours following their first dive until 24 hours following their final dive when counts were 1.67 (0.92-3.08) bubbles/eye. Bubble counts were not significantly correlated with inert gas load, body mass index, age or diving experience. We confirm that tear film bubble counts are raised following wet compressed air diving as previously described following dry diving.

Introduction

Following the serendipitous discovery of bubbles in the ocular tear film of a hyperbaric attendant following a dry chamber exposure to compressed air breathing,[1] several studies have demonstrated a relationship between the appearance of such bubbles and decompression stress in dry chamber dives. Bubble counts are uniformly increased following dry dives to PADI table no-stop limits between 12 and 36 m. Furthermore, counts increase with both increasing bottom times at a given depth and with exercise at depth, and are decreased following periods of oxygen breathing.[2-4] Tear film bubbles may be detectable in the absence of ultrasonic Doppler detectable venous bubbles and may persist for long periods following a compression exposure, typically up to 48 hours.[5]

Three possible practical uses may follow from these interesting observations. Firstly, counts may prove to be useful in estimating the decompression stress following standard depth, time and decompression exposures. This would assist in attempts to compare the risk of decompression sickness (DCS), between alternative diving schedules and in quantifying the risk of particular exposures. Secondly, repeated tear film examinations in individuals subject to frequent periods of compression and decompression might prove to be a sensitive monitor of mounting decompression stress. Finally, on a clinical level, tear film examination in symptomatic individuals may prove to be an important diagnostic aid in DCS.

To date, no data have been published on tear film bubbles in association with wet compressed gas diving. It is the aim of the present two studies to document the number of bubbles appearing in the lower lid tear film meniscus following single, repetitive, and multi-day compressed air diving in the marine environment. The specific hypotheses are that underwater compressed air diving causes an increase in the number of tear film bubbles that is sustained throughout multi-day diving and that bubble number is correlated with decompression stress.

Materials and Methods

Both studies were approved by the South Eastern Sydney Area Health Service Ethics Committee before commencement of enrolment and involved only adult volunteers who were appropriately trained and qualified to undertake scuba diving activity. Volunteers were excluded if they gave any history of ocular disease (apart from refractive errors), tear film dysfunction, medical reasons for not diving on the selected dive day, or if they had undertaken compressed gas breathing in the seven days prior to the study. Divers were equipped with standard recreational open circuit scuba with half-face mask and all dives were in seawater.

Study one: single day diving

45 volunteers were recruited from local dive clubs to undertake two air dives on a single day. A dive leader holding a minimum qualification of dive master was selected for each dive boat and all divers were instructed on the planned depth and time profiles. The first dive was to consist of a 25 minute dive to 25 m, followed by a controlled ascent to a safety stop of 5 minutes at three m. After a surface interval of 1.5 hours, a second dive was made to 20 m for 25 minutes with similar ascent rates and safety stop. Each of these was designed to fall within the maximum no-stop dive time allowed (PADI tables). All dives were recorded on personal depth and time recorders and later downloaded using commercial software (Datatrak, v2.03, Dynatron AG, Zurich). Water temperature varied from 17° to 20° C (63° to 68° F).

The ocular tear film bubbles on each eye were counted prior to diving, then again at 1 hour, 12, 24, 48 and 72 hours post-diving using a slit lamp (SL900, Haag-Streit, Switzerland) employing a standard technique described elsewhere.[6] Briefly, the subject is examined by sweeping the slit across slowly from the medial to the lateral border of the inferior tear film gutter, counting bubbles, if any. It is important to limit the inspection to the gutter itself in order to standardise the examination and because small bubbles on the lid itself are not uncommon as a result of physical foaming after blinking. The subject is asked to close their eyes for 5 seconds, open them again and the examination is repeated. Three sweeps are made and the bubble count averaged before the procedure is repeated in the other eye.

Study two: repetitive, multi-day diving

Eleven adult divers who were planning to undertake a series of ten compressed air dives over a five day period were recruited. No attempt was made to standardise the individual dives, however, all were undertaken in the same series of dive sites and the depth and time profiles were recorded as for study one. Water temperature for this series of dives was 24° to 28° C (75° to 82° F).

Ocular tear film examinations were made, by the standard method described above, prior to the first dive, within two hours of completion of each day's diving and then at 24, 48 and 72 hours following the last dive. All volunteers completed at least 7 of the planned dives and 9 of 11 divers completed all examinations.

Statistical analysis

Both volunteer groups were recruited as a convenience sample and no power calculations were made concerning any magnitude of difference in tear film bubble counts. Median tear film bubble counts per eye were compared using the Friedman test for multiple comparisons (a non-parametric equivalent of ANOVA). The Shapiro-Wilk W test for non-normality was employed on bubble count distributions and the Mann-Whitney U test for individual comparisons of bubble counts when distributions were unlikely to be normal.

In study one, the effect of potentially important determinants of bubbles in individual divers (age, body mass index [BMI] and previous diving experience) was examined using non-parametric correlation and regression (Kendall's rank correlation method, which provides a distribution free measure of the strength of dependence between two variables). In study two, the possible relationship between bubble count in individuals and decompression stress was examined using the same statistical methods. An index of tissue inert gas loading was used as an estimate of decompression stress for each dive. The gas-loading index was calculated as the product of maximum gauge pressure (in metres of seawater) during a dive and the square root of total bottom time ($P\sqrt{T}$).[7] For each diver, $P\sqrt{T}$ was summed for all dives each day (daily gas load) for comparison with daily bubble scores and $P\sqrt{T}$ was summed for all dives in the 5 day period (cumulative gas load) for comparison with peak and cumulative bubble scores.

All calculations were made using StatsDirect statistical software, version 1.611, (Iain Buchan, 2000).

Results

STUDY ONE

45 divers entered the water for the first dive and the spread of maximum depths and in-water times recorded are shown in Figure 1. Three individuals had markedly different profiles (In-water time <12 mins and/or maximum depth <20m) and these individuals were excluded from further analysis.

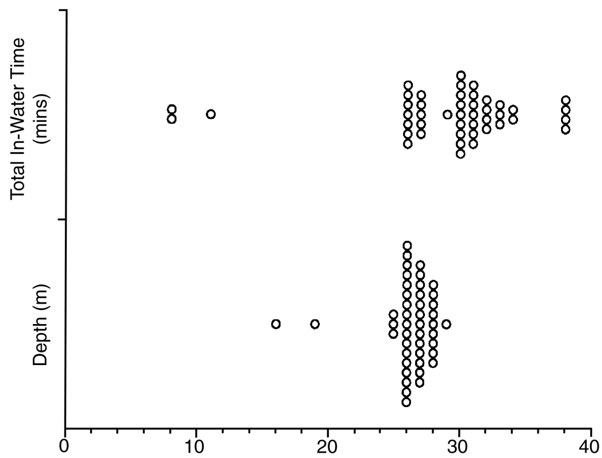

Figure 1. Dive one: depth and time exposures for all divers in study 1. X-axis is metres of seawater or minutes. The three individuals with dive time less than 12 minutes were excluded from analysis.

Due to inclement weather and water conditions, only 31 divers undertook the second dive. Most completed the planned depth and time exposures, although three individuals spent 47 to 48 minutes at 15 to 16 m and one further individual spent 34 minutes at a maximum depth of 28 m. These individuals were retained in the analysis. The spread of exposures to both depth and time is shown in Figure 2.

Of the 42 divers included in the analysis, 10 were female. The included group had a mean age of 32.7 yrs

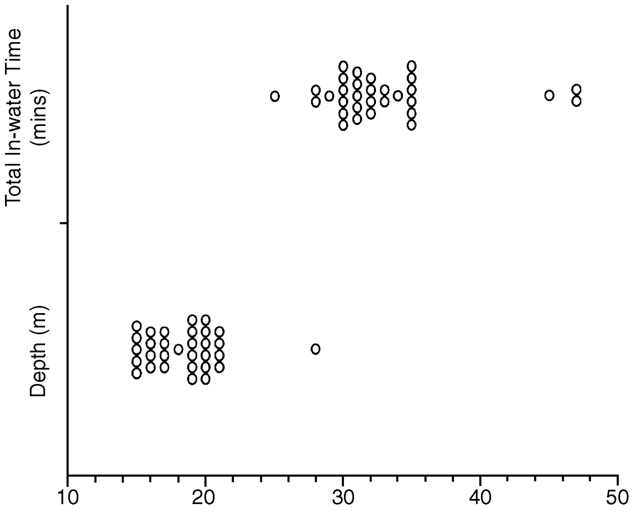

Figure 2. Dive two: depth and time exposures for all divers in study 1. X-axis is metres of seawater or minutes.

(SD 9.0 yrs, n=42), average body mass index (BMI) of 25.6 (SD 4.6, n=42) and a wide range of previous diving history. Median years of diving activity were 4 years (range 0.4 to 41) and median number of previous dives was 100 (range 3 to 5,000). Four subjects were regular smokers.

Fifty six of the 84 eyes (66.7%) showed no bubbles on examination prior to diving and 47.6% of subjects (20/42) showed no bubbles in either eye at this time. Maximum bubble numbers were seen at 48 hours following diving, although the numbers of eyes and individuals who remained bubble free was still substantial at 34.5% of eyes (29/84) and 23.8% of individuals (10/42). The distribution of bubbles prior to diving and at 48 and 72 hours is shown in Figure 3. The distributions are unlikely to be normal at any examination (*P* ≤0.0001, Shapiro-Wilks W test).

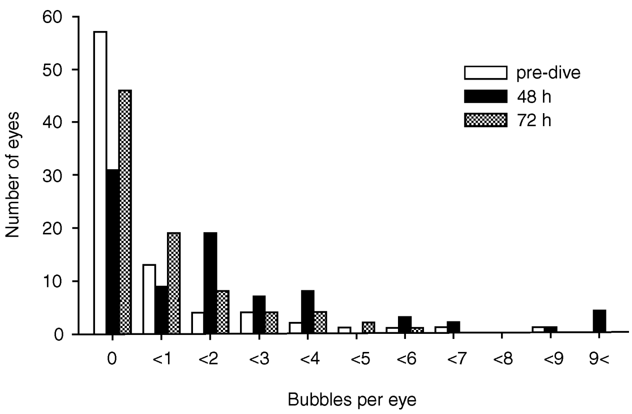

Figure 3. Bubble counts in individual eyes at pre-dive, 48 hours and 72 hours following diving in study 1. Bubble counts are the average of 3 sweeps and are grouped from left to right as 0, 0< to <1, 1 to <2, 2 to <3, etc.

Median and inter-quartile range tear film bubble counts per eye for all examinations are shown in Figure 4. The Friedman test yields a significant value ($P \leq 0.0001$), suggesting a true difference in bubble counts between at least two groups. Friedman multiple comparisons model yields statistically significant differences between pre-dive bubble counts and counts at all examinations except 72 hours, (versus post-dive $P < 0.0001$, 12 hours $P = 0.001$, 48 hours $P < 0.0001$, 72 hours, $P = 0.09$).

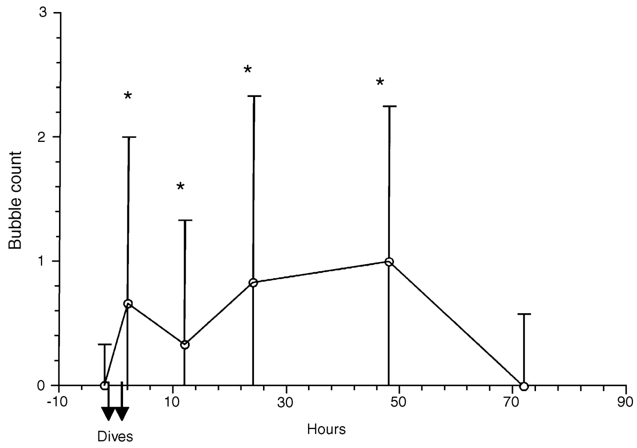

Figure 4

Figure 4. Median bubble counts in individual eyes before and after single day diving in study 1. Arrows on x-axis indicate the time of the two dives. Error bars are inter-quartile range. Asterisks indicate significant different from pre-dive ($P<0.05$).

Bubble counts at 48 hours after diving were compared between those completing one dive versus those completing both dives, however there was no significant difference ($P = 0.82$, Mann-Whitney U test). A similar analysis was made to compare bubble numbers in males versus females and those who wore contact lenses. While there was a trend to more bubbles in females, this was not statistically significant (median difference females 0.5 bubbles more per individual, 95% CI -0.33 to 2.0, $P = 0.14$). Eight divers wore soft contact lenses while diving and all kept them in during the examinations. The area under the contact lens was not examined for bubbles and there were no significant differences in inferior tear film meniscus bubble counts between those with and without lenses (at 48 hours, 1.3 bubbles/person with lenses, versus 1.6 without, $P = 0.69$, Mann-Whitney U test).

The relationship between bubble counts at 48 hours and age, diving experience and BMI were examined using Kendall's rank correlation coefficient (RCC) and non-parametric linear regression. No significant relationships were evident (with age: $P = 0.91$, RCC -0.01, total dives logged: $P = 0.53$, RCC 0.54 and BMI: $P = 0.36$, RCC -0.11).

STUDY TWO

Eight divers completed all 10 dives, one diver completed only 7 dives, one completed 8 dives, and another 9 dives. Overall, the mean maximum depth of each dive was 23.0 metres (SD 4.6m, n=104) and the mean time underwater for each dive was 44.0 minutes (SD 5.5 min, n=104). Mean P√T for each individual dive was 151.4 (SD 27.8, n=104) and mean daily gas load was 288.2 (SD 69.3, n=55). The cumulative gas load for the 5 day period for each diver is shown in Figure 5.

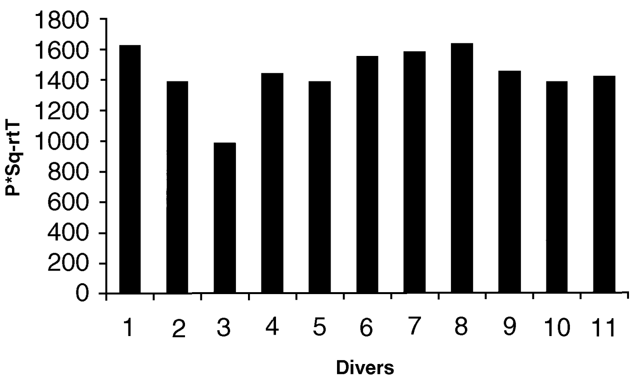

Figure 5. Cumulative inert gas load index for each diver in study 2. Bars show the sum for all dives during the 5 day period.

Median tear film bubble numbers and inter-quartile range for each examination are shown in Figure 6. The bubble counts rose over the period of diving (days 1-5) and then decreased until at 72 hours (day 8 examination) they were not significantly different from the pre-dive count. As with study one, the distributions of bubbles at each examination were unlikely to be normal ($P < 0.05$, Shapiro-Wilks W test), making comparisons using ANOVA unhelpful.

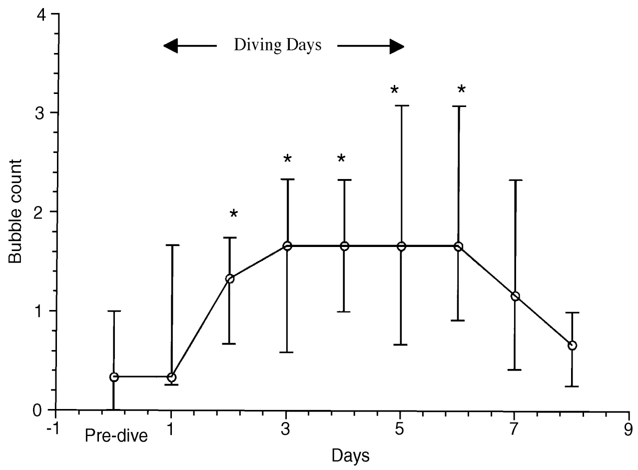

Figure 6. Median bubble counts in individual eyes during study 2. Dives were conducted on days 1-5 as indicated by the arrows. Error bars are inter-quartile range. Asterisks indicate significant different from pre-dive (P<0.05).

The Friedman test yields a significant value ($P \leq 0.0001$) and suggests a true difference in bubble counts between at least two groups. Friedman multiple comparison model yields statistically significant differences between pre-dive bubble counts and counts at days 2 to 6 (versus day 1 $P = 0.21$, day 2 $P = 0.0009$, day 3 $P < 0.0001$, day 4 $P < 0.0001$, day 5 $P < 0.001$, day 6 $P < 0.0001$). Similar comparisons with counts on days 7 and 8 could not be made because of data loss.

Three possible relationships between gas load and bubble counts were examined using non-parametric regression and correlation. Daily gas load was correlated with the bubble count taken 24 hours following the end of that day's diving. However, this correlation is difficult to interpret because tear film bubbles following diving persist for longer than the interval between the daily diving exposures. Therefore, for each diver, cumulative gas load was correlated against both peak (day 6) bubble counts and against cumulative bubble counts (sum of bubble counts for days 1-6). Table 1 lists the assumptions implicit in these models and the results of these analyses, none yielded any significant relationship.

TABLE 1

REGRESSIONS OF BUBBLE COUNTS AGAINST P√T IN STUDY 2

Correlation and Regression	Assumption Regarding Diving	Kendall Regression Correlation Co-efficient (RCC)	*P*-value
Bubbles Day 6 and cumulative PT	Decompression stress cumulative	-0.17	0.45
Bubbles 24 hours after each diving day and P√T for that day	Decompression stress each day independent	-0.01	0.88
Cumulative total bubbles and cumulative P√T	No assumption	0.05	0.88

INTER-OPERATOR VARIABILITY

In study one, four slit-lamp operators were involved in the tear film examinations. Two examiners performed the majority of eye examinations (386/540, 71.5% and 120/540, 22.2% of examinations respectively). There was some inter-examiner variability between these two operators. The principle operator counted a median of 0.33 bubbles less per eye than the second operator, 95% CI -0.66 to 0 bubbles, $P < 0.01$ (Mann-Whitney U test). In study two, a single operator (MB) performed 91% of examinations. Two others performed the remaining 9%. There were no significant differences between operators and bubble counts recorded in this study between the principal operator and all others ($P = 0.92$, Mann-Whitney U test).

Discussion

With these studies we have established for the first time the presence of an increased number of bubbles in the lower tear film meniscus following compressed air breathing in the marine environment. The numbers of bubbles detected are a little lower than those found after dry dives in a hyperbaric chamber (1,2,3), and it is possible our technique for the detection of bubbles is somewhat less sensitive than those described by these authors. The persistence of bubbles in significant numbers for 48 hours after decompression is consistent with previous findings.[5] Regardless of continued diving (within PADI table limits), bubble counts rise 24 hours after the first dive and remain elevated and stable while diving continues and for 24-48 hours after the last dive.

Contrary to previous reports, no correlation was found between number of tear film bubbles following diving and different levels of decompression stress.[2] This is probably a limitation of the present studies. In study two, it is clear from the coefficient of variation of the maximum diving depth (20%), time underwater (13%), and daily decompression stress (24%) that the pattern of diving was relatively homogeneous. Tear film bubble count may be insensitive to small variations in decompression stress. Similarly in study one, no difference in tear film bubble number was found between divers who completed one or two dives, but both the single and repetitive dives schedules were at the no-stop limit and may result in similar decompression stress.

The persistence of tear film bubbles for at least 48 hours following diving also complicates the correlation of daily bubble counts with daily decompression stress during multi-day diving. Firstly, bubbles detected on any particular day may represent the decompression stress 24 or 48 hours previously. Correlation of cumulative bubble counts with cumulative decompression stress (both sums across all days) is free from any assumed temporal relationship, but was not significant. Secondly, although common decompression algorithms do not account for cumulative decompression stress between dives separated by more than 18 hours, decompression stress may accumulate, for instance in the presence of stable tissue-bubble complexes. Correlation of peak (day 6) bubble counts with cumulative decompression stress assumes bubble counts represent a cumulative effect of all dives, but was not significant. However, in both cases tear film bubble count may be insensitive to the relatively small variation in cumulative decompression stress (coefficient of variation = 12%).

$P\sqrt{T}$ is an index of diffusion limited inert gas uptake at the end of dives with bottom time of less than 100 minutes duration.[7] As the actual depth/time profile and subsequent decompression is not considered, it is not a true measure of decompression stress per se. However, such classification of dives according to maximum depth and duration has proved useful as an index of decompression severity even amongst quite different decompression practices.[8] In study two, diving practices were sufficiently similar to justify use of $P\sqrt{T}$.

While the differences described in these studies are statistically significant, they are small in magnitude. There is no known pathological implication from the finding of increased bubble numbers of any magnitude in an individual. Furthermore, the observation of increased tear film bubbles following diving does not prove a causal relationship between compressed air breathing and ocular bubbles. A series of further studies are under way at the Prince of Wales Hospital to investigate any correlation between such bubbles and other activities such as running, swimming or snorkelling. If bubble counts are not raised after these activities, the case for a causal relationship between bubbles and diving will be strengthened.

Doubt remains as to the origin of these bubbles. Four possible sources have been suggested, none of which is supported by good evidence at this point. The bubbles may arise from vascular structures in the conjunctivae or from the aqueous humour and move by diffusion to the interstitium of the conjunctivae and thence into the tear film. This is most useful in explaining early bubbles following a decompression such as those described in previous small studies of dry diving. The time course of such bubbling is likely to be short and parallel the detection of central venous ultrasonic Doppler bubbles after decompression. The persistence of bubbles for 48 hours is more difficult to account for by this mechanism, although secondary diffusion from a more remote source is one possibility.

It has been suggested the bubbles may arise from the Meibomian (Tarsal) glands located in the upper and lower lids.[3] These are enormously enlarged holocrine sebaceous glands and open directly onto the palpebral margin. The glandular cells have an increasingly high lipid content as they mature and are the source of the lipid layer of the tear film, probably introduced to the other layers with blinking.[9,10] After a variable maturation period from days to weeks, the gland cells rupture into a short central duct and thence into the tear film. It is possible that bubbles may arise in these lipid-containing cells on decompression and remain stabilised in the lipid environment until discharged into the tear film with the lipid cell contents. While this more easily explains the persistence of bubbles than the vascular theory, such bubbles have not been reported emerging from the Meibomian glands during our study. On the other hand, bubbles and glandular excreta following pressure to the area of the glands has been reported.[3]

A third mechanism of bubble generation into the tear film may be the evolution of gas from the peri-scleral lipid tissue or sclera itself. The relatively long time course for the detection of these bubbles may reflect the ability of lipid structures to retain stabilised bubbles over this period. The fourth potential source of bubbles is the lacrimal gland, source of the aqueous and most voluminous of the tear film layers. There does not appear to be any substantial support for this proposition either experimentally or physiologically.

One third of individuals in study one had some bubbles in their tear films prior to diving. Whatever the actual source of bubbles following diving, this figure would indicate a mechanism for the generation of bubbles independent of compressed air breathing. Most ophthalmologists the authors have questioned have not previously noted bubbles during routine slit-lamp examinations. This may not be surprising, however, as these bubbles have no known significance and may pass unnoticed even when present. It seems most likely that the occasional bubbles seen prior to diving are caused by mechanical action during blinking or other ocular and peri-ocular movement. It may be that increased counts following diving merely reflect an increase in mechanical activity in and around the tear film meniscus. A study underway at present in our unit is an attempt to answer the question as to whether exposure to the marine environment and exercise in the water also raise tear film bubble counts.

Slit-lamp operator error is a possible confounder in the present studies, particularly as the operators were not masked to diving exposure. The two principle operators in study one detected bubbles to a significantly different degree in the eyes they examined. The technique described is likely to be highly subject to variations due to different sweep speeds, vigilance and familiarity with the instrument. We have overcome these sources of error as much as possible by developing a standard written protocol and frequent comparisons of technique through the study period. The practical limitations of the study, however, did not allow us to produce multiple operator data for each subject at each examination, or to develop a masked comparison with a control group. Further studies should develop such methodologies or adopt a more objective and standard technique for bubble estimation. A technique using photography and volumetric measurements of bubbles has been reported.[3] We feel the advantage of our approach lies in the minimal equipment required, allowing the possibility of remote clinical diagnosis of significant decompression stress.

It is certainly our clinical impression from a small number of divers attending for the treatment of DCS, that bubble counts may be raised on presentation and subside with oxygen breathing at depth. If tear film bubble counts are to prove useful as a diagnostic tool, future studies will have to demonstrate a significant relationship between decompression stress and bubble counts by examining patients presenting for treatment with clinical evidence of DCS.

We have demonstrated a modest, but statistically significant, rise in bubble counts following compressed air diving within PADI table limits. These modest rises may be of use in comparing decompression stress for putative or experimental dive profiles. Future studies may attempt to develop tear film bubble counting as a method of differentiating those with DCS from those in which DCS is unlikely.

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Declaration

The authors declare that we have no financial interest in any commercial product involved in this research and received no financial assistance for the conduct of these studies.

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NEUROLOGICAL SYMPTOMS DEVELOPING WHILE DIVING

R M Bateman and R N Sawyer Jr

A 25 year old woman presented with left sided weakness and a patchy right sided sensory loss, which developed while diving in Egypt.

Recompression therapy was started, leading to an unsustained improvement in symptoms and signs.

Magnetic resonance imaging for here cervical spine subsequently showed a lesion at the level of C4 (Figure 1) and transverse myelitis was diagnosed. The patient may a nearly full recovery after steroids were given.

This case illustrates the importance of a thorough neurological examination for all suspected cases of decompression illness. It is also a poignant reminder that neurological symptoms and signs in divers may be due to neurological disease other than decompression sickness.

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