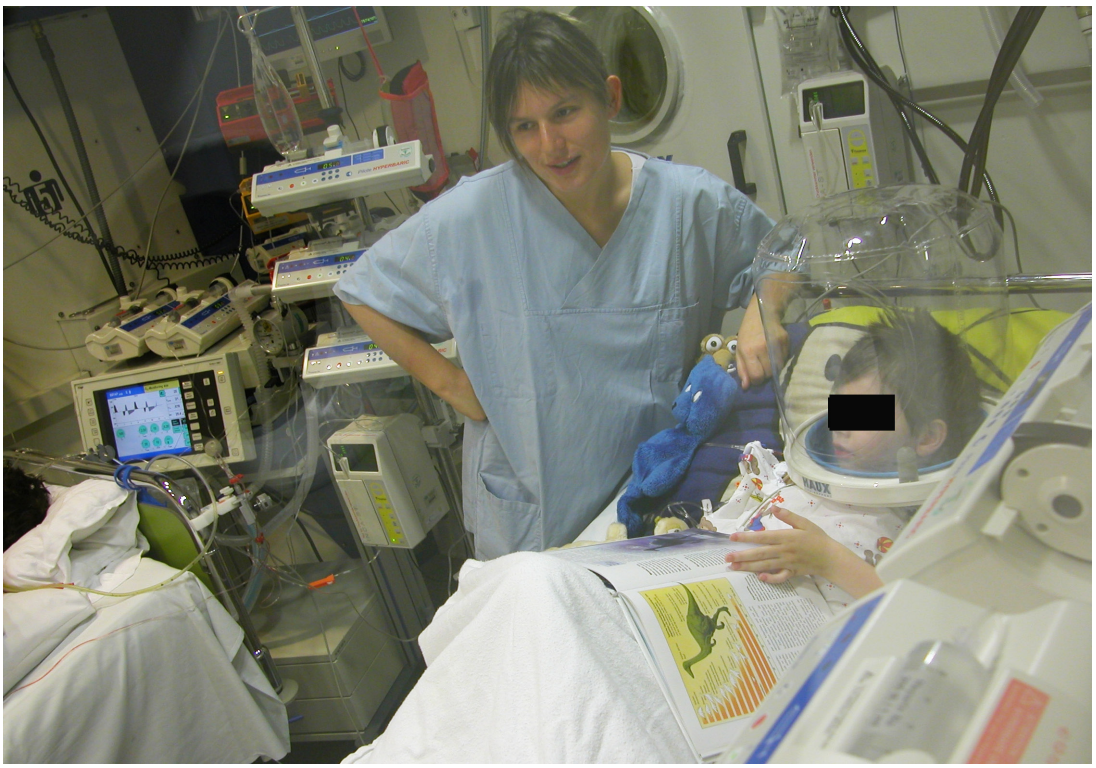
Diving and Hyperbaric Medicine

The Journal of the South Pacific Underwater Medicine Society (Incorporated in Victoria) A0020660B and the European Underwater and Baromedical Society

SPUMS

Volume 42 No. 3 September 2012

EUBS



HBOT does not improve paediatric autism

ISSN 1833 - 3516
ABN 29 299 823 713

Print Post Approved
PP 331758/0015

PURPOSES OF THE SOCIETIES

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 and to convene members of each Society annually at a scientific conference

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Diving and Hyperbaric Medicine **is published jointly by the South Pacific Underwater Medicine Society and the European Underwater and Baromedical Society**

The Editor's offering

A search of the web on treating autistic children with hyperbaric oxygen therapy (HBOT) brings up thousands of hits; medical articles,[1] videos, blogs from hyperbaric chambers and parents, television and other news media items, even a *Scientific American* news blog. Many of these sources enthusiastically advocate HBOT, even though autism does not appear in any of the SPUMS/ANZHMG, EUBS or UHMS lists of accepted indications for HBOT.

A Canadian study, in which 24% oxygen at 1.3 ATA (131 kPa) was compared with air at slightly over normobaric pressure (1.03 ATA), reported improvement in various neurobehavioural parameters in both groups, but significantly more so in the 'mild hyperbaric therapy' group.[2] However, this study does not test HBOT, as the oxygen component was only the equivalent of an F_IO_2 of about 0.32 at 101.3 kPa. Also, as Bennett has pointed out (unpublished observation, 2011) the paper reports a difference in the change in outcome measure compared to baseline, not the absolute value at the end of the trial, and there is no difference between the groups when this is analysed.

The European Committee for Hyperbaric Medicine at its 2010 workshop, in reviewing the use of HBOT for autism, and including this study, concluded "*Currently there is no clear rationale for HBOT in autism based on clinically proven pathophysiological mechanisms. The few studies on the use of pressurized environments (not always compatible with the definition of 'hyperbaric oxygen therapy') for autism have serious methodological limitations...HBOT should be used only within the framework of an ethically approved clinical trial.*"[3] In a recent systematic review of HBOT for treating autism, 18 publications were identified.[4] Two studies were randomised, double-blind, controlled clinical trials. While some studies suggested that HBOT was effective, the conclusion of this review was that these promising effects are not replicated. Therefore, sham-controlled studies with rigorous methodology are still needed in order to provide evidence-based data on HBOT therapy in autism.

In this issue, Sampanthavivat and his colleagues in the Royal Thai Naval Medical Department report on just such a carefully controlled RCT, with a sample size based on a pre-study power analysis of their unpublished pilot study.[5] In the present study, HBOT at 153 kPa (1.5 ATA) was compared with air at 116 kPa (1.15 ATA) in 58 children. Both groups had significant improvements in overall behaviour. However, despite some inconsistent changes in some of the parameters studied which were difficult to interpret, overall, no significant benefit from HBOT could be shown.

In both this and the Canadian study, only the short-term outcome at the end of the study was measured, whereas longer-term follow up would be useful. It is to be hoped that this may yet be possible in the Thailand study. Nevertheless, these are important data contributing to the evidence base for hyperbaric medicine, and highlight the dangers of unsubstantiated enthusiastic adoption of HBOT for what the UHMS describes as "*off-list*" conditions, such as multiple sclerosis and cerebral palsy as two other neurological examples. Such practice only brings hyperbaric medicine into disrepute within mainstream Western medicine and masks our increasing understanding of the underlying pathophysiological mechanisms that explain why high-pressure oxygen has a therapeutic role in some clinical conditions.

Changing the subject, two aspects of the Australian diving fatality reports that have struck me are the number of divers labelled as 'obese' and the frequency of lack of buoyancy control being a likely factor in the tragedy. Reviewing the past four years' reports shows a quarter of scuba divers were obese and over another third overweight. What is probably more important than these labels is how they reflect on lack of physical fitness, especially in the obese diver. I have seen many novice divers being taught to dive overweighted and to use their buoyancy compensator to achieve neutral buoyancy – a poor diving practice. Both of these aspects – the importance of physical fitness for safe scuba diving and buoyancy control training – need to be better addressed by the dive training agencies in order to help reduce fatalities.

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Key words
Autism, hyperbaric oxygen therapy, research, editorials

Michael Davis

The front page photo was taken in the chamber at the Druckkammerzentrum, Unfallklinik Murnau, Germany and shows Nurse Nicole Maier keeping a young patient interested whilst undergoing HBOT.

The Presidents' pages

Michael Bennett, President SPUMS

In this, my fourth AGM report, I wish to begin by thanking the members present for continuing to support our Annual Scientific Meeting with their attendance. I am certain they will agree with me that Cathy Meehan has done a tremendous job organising this meeting – both from a social and scientific point of view. The location has proved everything she promised and the very minor problems with travel and the dive operations were well beyond her control. I think we all agree, the scientific programme has been extraordinarily well received and of the highest possible calibre.

Richard Fitzpatrick had us entranced with the subject of sharks and now we know both how to hypnotise a shark should we ever need to do so, and that the end with teeth is only marginally more dangerous than the bit where you hypnotise them. Sharks are cool, but Jamie Seymour quite rightly exhorted us to see that there are a number of other equally cool animals with hundreds of ways to bring us down. Nobody who attended this meeting will ever forget the energy and enthusiasm he brought to the meeting and we should all aspire to approach our own careers with a fraction of the delight and commitment Jamie shows us.

I particularly want to thank those who presented free papers. I do not recall any previous meeting where we have seen so much original work; this ASM of ours becomes more and more a true contributor to the totality of scientific and medical knowledge in our field with each passing year. The founding fathers (yes, I think they were all men) would surely be impressed and proud of what they have created here. I am particularly gratified to hear from more than one attendee this year that for them, while we all come hoping for some great diving, the scientific programme is the core of the week – the event that defines why they come to SPUMS. It is always a lot of work to prepare these free papers and, on behalf of SPUMS, we salute all presenters at this meeting. The ASM could not continue without these unsolicited contributions, and I hope those who already contribute continue to do so. I encourage others to follow their lead.

Over the last year, the focus of the Committee has continued to be directed to three particular areas. First, we have continued our formal association with the European Undersea and Baromedical Society as joint owners of the Journal. This arrangement has been a nearly unqualified success. The Journal, under our ever-vigilant editor, Mike Davis, moves from strength to strength and we have heard a wonderful presentation from Mike about where we have been, where we are and where we are going.

Secondly, the Committee has been dealing with issues relating to the position of Treasurer for the Society, and in particular on the formal separation of roles relating to the Society on the one hand and the Journal on the other. The Committee in general and Mike Davis in particular are grateful to Jan Lehm for his efforts over the last year to help make the positions of both entities increasingly clear. While we will not have Jan's services as Treasurer for much longer, we hope he will continue to offer his knowledge and expertise to the next incumbent. The next great project will be the formalisation of a separate financial record for the Journal and almost inevitably the employment of a professional book-keeper for the Society; more of that later.

Thirdly, we have continued to struggle with our falling membership. We have a number of strategies in place and are very keen to hear ideas from the members. We remain convinced that many doctors who dive have no knowledge of our existence and we are also concerned that the numbers of doctors prepared to perform diving medicals is contracting rather than expanding. To this end, we have developed a 'SPUMS promotional pack' that will be available on the website. Any member who wishes to do so is free to use this material.

To conclude, I wish to mark the retirement from the Committee of one of the stalwarts of SPUMS. Guy Williams has done a fantastic job for this Society over many years as a committee member, President and most particularly in the hard and unglamorous role of Treasurer. He will be sorely missed. Thank you for all your hard work, Guy.

I believe SPUMS looks to the future with more confidence than we did 12 months ago. Please stay on the road with us and consider inviting your colleagues and friends along.

Key words
Medical society, meetings

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Peter Germonpré, President EUBS

Dear friends,

As you read this, we have entered a new era. Well, at least for me, as I will no longer be the President of EUBS by the time this issue of our Journal is mailed out. I have served my three years as President, and now leave this post to my good friend, Tino Balestra. No doubt he will have a different style, but rest assured of his motivation and full determination to continue the path our Society has taken.

It is with great satisfaction that I look back upon these three years. I have been lucky enough to be surrounded by enthusiastic colleagues, and I believe we have achieved a lot. Our future projects will build further on these fundamentals, and I invite you all to play an active part in these.

No doubt, we will have had a very successful Annual Meeting in Belgrade, preceded by a Consensus Meeting of the European Committee for Hyperbaric Medicine (ECHM), a dedicated EUBS pre-conference workshop on "*Research in hyperbaric medicine"*, and followed by a DAN Divers' Day. A full week's scientific programme – some would call it a luxury; others would complain there is not enough time to 'socialise'. In any case, it shows clearly that the hyperbaric and diving medicine community does not fall short of discussion topics and I have to pay tribute to those individuals who have spent countless hours of their time to get it all organised. Experience has shown that scientific networking is boosted to some extent for at least a couple of months after each Annual Meeting.

Our next 'big project' will be the Tri-Continental Scientific Meeting on Diving and Hyperbaric Medicine (Réunion Island, 21–28 September 2013), so if you have not done so already, please block your agendas, visit the website: <www.reunion2013.org> and start saving for the trip. The next meetings will be in Germany (2014) and The Netherlands (2015), and a candidacy has been received for Croatia in 2016. As reflected in our renewed membership growth tendency, our Society is alive and kicking and has not lost its attractiveness. However, more members are needed and you are (again) urged to stimulate your colleagues to join EUBS, even if they are already a member of your country's national scientific society – EUBS membership complements a 'national' membership, especially with our excellent Medline-indexed Journal as part of a very reasonable subscription!

So it is "*goodbye*" from me now. I will, of course, remain active in the EUBS ExCom, as well as with managing the website, so no doubt you will hear from me from time to time. I will not, however, speak to you again through this medium – that is a job for the new President.

Key words
Medical society, meetings

Original articles

Hyperbaric oxygen in the treatment of childhood autism: a randomised controlled trial

Mayuree Sampanthavivat, Wararat Singkhwa, Thanasawat Chaiyakul, Sangdaw Karoonyawanich and Haruthai Ajpru

Abstract

(Sampanthavivat M, Singkhwa W, Chaiyakul T, Karoonyawanich S, Ajpru H. Hyperbaric oxygen in the treatment of childhood autism: a randomised controlled trial. *Diving and Hyperbaric Medicine*. 2012;42(3):128-133.)

Background: Promising results with hyperbaric therapy for children with autism have been reported, but most involved the use of only mild pressure with oxygen supplementation. To date, there has been no randomised, blinded trial of 100% oxygen administered at hyperbaric pressure. This study evaluated the efficacy of hyperbaric oxygen therapy (HBOT).

Methods: Sixty Thai children with autism, aged three to nine years, were randomly assigned to receive 20 one-hour sessions of either HBOT at 153 kPa (1.5 ATA) or sham air at 116 kPa (1.15 ATA). Effects on behaviour were measured using the Autism Treatment Evaluation Checklist score (ATEC) and clinical improvement was measured with the Clinical Global Impression (CGI) system; in particular the clinical change (CGIC) and severity (CGIS) sub-scores. These were evaluated by parents and clinicians, both of whom were blinded to the actual exposure.

Results: The mean total ATEC scores by both parents and clinicians were significantly improved after intervention in both arms of the study compared to the score before intervention ($P < 0.001$ in both groups by parents, $P = 0.015$ in HBOT group and $P = 0.004$ in sham group by clinician). There were no statistically significant differences in average percentage changes of total ATEC score and all subscales scores when comparing the HBOT and sham air groups, either by parents or clinicians. Changes in the CGI scores following intervention were inconsistent between parents and clinicians. For severity scores (CGIS), parents rated their children as more improved following HBOT ($P = 0.005$), while the clinicians found no significant differences ($P = 0.10$). On the other hand, for change scores (CGIC) the clinicians indicated greater improvement following HBOT ($P = 0.03$), but the parents found no such difference ($P = 0.28$)

Conclusions: Children with autism who received 20 sessions of either HBOT or a sham air exposure had significant improvements in overall behaviour but there were no significant differences in improvement between groups. The inconsistent changes on CGI sub-scores between parents and clinicians are difficult to interpret, but no overall clinically significant benefit from HBOT could be shown. Both interventions were safe and well tolerated with minimal side effect from middle ear barotraumas.

Key words

Autism, hyperbaric oxygen therapy, hyperbaric research

Introduction

Autism is a condition classified within the group of pervasive developmental disorders, characterised by a triad of clinical findings including qualitative impairments in speech and communication, impairments in social interaction and in stereotyped patterns of behaviour, interest and activities.[1] Global prevalence of autism is estimated at approximately 22 cases per 10,000, and there is a trend of increasing rates of prevalence by years.[2] In Thailand, the prevalence of autism in children aged one to five years is estimated at 4.4 per 10,000.[3] The gender ratio (male: female) of children with autism in Thailand was 3.3:1 and in the UK was 6.5:1 children.[4,5] Behavioural interventions are the mainstay of therapy for individuals with autism, while several drug therapies have been used to treat some target behaviours, including antipsychotics, antidepressants and psychostimulants.[6] At present, risperidone is the only medication approved by the US Food and Drug Administration to treat irritability in autism. Hyperbaric oxygen treatment (HBOT) has been suggested recently as a useful adjunctive treatment in children with autism.

Accepted indications for HBOT include air or gas embolism, carbon monoxide poisoning, clostridial myositis and myonecrosis, crush injury, decompression sickness, severe anaemia, intracranial abscess, necrotizing soft tissue infections, osteomyelitis, delayed radiation injury, compromised grafts and flaps, and acute thermal burn injury.[7] In some places, and without good clinical evidence, HBOT is also used as an adjunctive treatment in other conditions including ischaemic cerebral strokes, traumatic brain injury and cerebral palsy.[8–11] HBOT is generally considered relatively safe at pressures below 304 kPa for less than 2 hours.[12,13]

Evidence of cerebral hypoperfusion, neurological and gastrointestinal inflammation, immune dysregulation,

oxidative stress and relative mitochondrial dysfunction have all been associated with core autistic symptoms. Repetitive self-stimulatory, stereotypical behaviours and impairment of communication, sensory perception and social interaction have all been found in case subjects with cerebral hypoperfusion.[14–16] HBOT has been reported to have a beneficial effect on inflammation, improving cerebral hypoperfusion and modulating immune dysregulation.[13–15,17–20] A randomised, double-blind, controlled trial comparing the effect of 'hyperbaric treatment' consisting of 24% oxygen at 1.3 ATA, to that of slightly pressurised room air at 1.03 ATA, has been reported recently.[21] This trial showed significant improvements in the ATEC score in several domains including total score, sociability, sensory/cognitive awareness and health/physical/behaviour in the treatment group while in the control group improvements were found in total score and sociability. There were important differences between the groups at baseline in this small trial, making interpretation of the results difficult. Direct comparison between groups after the treatment found a significant improvement only in sensory/cognitive awareness.[21] There were several position statements from international societies considering such previous case series and trial controversial by using low pressure/low oxygen concentration hyperbaric treatment.[22,23]

Our open-label pilot study suggested a statistically significant effect on behaviour after completion of 20 sessions of hyperbaric oxygen treatment at 153 kPa (1.5 ATA) for one hour daily (unpublished data). Since only slightly oxygen-enriched air was used in the previously published randomised study, rather than hyperbaric oxygen, the objective of this study was to evaluate the effects of 'true' HBOT on children with autism.

Methods

ETHICAL APPROVAL

This study was approved by the Ethics Committee (Institutional Review Board) of the Royal Thai Navy Medical Department.

PROCEDURES

This study was a prospective, randomised, double-blind, controlled trial of HBOT at 153 kPa (1.5 ATA) with 100% oxygen for one hour daily, weekdays to a total of 20 sessions, versus a sham air treatment consisting of pressurised room air at 116 kPa (1.15 ATA) on the same schedule. Parents or caregivers were allowed to accompany their children along with one medical attendant. 116 kPa (1.15 ATA) was employed in the sham air group because this is the minimum pressure required to keep our multiplace chamber tightly closed and therefore to closely mimic the experience of hyperbaric treatment, in order to maintain blinding of participants and parents.

PARTICIPANTS

Children, aged three to nine years, diagnosed with autism according to DSM-IV TR™, and who had never received HBOT, were considered for inclusion in this study. Children who had seizure disorders, uncontrolled asthma, a history of previous spontaneous pneumothorax, current ear or upper respiratory tract infections, emphysema, current or recent chemotherapy, severe claustrophobia, and ongoing chelating therapy were excluded from the study. Written, informed parental consent was obtained before randomised allocation to treatment group (see below for details of randomisation and allocation concealment).

CLINICAL OUTCOME AND MEASURES

The primary outcome measures were changes of behaviour evaluated by comparing the Autism Treatment Evaluation Checklist (ATEC) scores and Clinical Global Impression (CGI) scale evaluated separately by clinician and parents before and after 20 sessions of interventions.[24–26] The ATEC consists of 4 subtests: I. Speech/Language Communication (14 items); II. Sociability (20 items); III. Sensory/ Cognitive Awareness (18 items); and IV. Health/Physical/Behaviour (25 items). The ATEC scores were analysed as absolute and percent changes of average total and subscale scores.

The Clinical Global Impression of Illness Severity (CGIS) scores were assessed before and after the interventions. The CGIS is rated on a 7-point scale using a range of responses from 1 (normal), 2 (borderline mentally ill) to 7 (among the most extremely ill patients). Average scores for the two groups were compared before and after the interventions. The Clinical Global Impression of Change (CGIC) scores were assessed after the interventions to score the improvement of each participant. CGIC scores range from 1 (very much improved), to 7 (very much worse). Average scores for the two groups as rated by both parents and clinicians were compared.

SAMPLE SIZE

Pre-study power analysis was based on the differences in means and standard deviations of ATEC score changes in our pilot study since there were no comparable data in any previously published studies. In order to achieve 80% power ($\beta = 0.2$, $\alpha = 0.05$), we calculated that we would require 24 participants. To allow for some withdrawals, we planned to recruit a total of 60 participants.

RANDOMISATION AND ALLOCATION

Sixty-one children were assessed for eligibility; one child was excluded after consent, but before treatment allocation, owing to parental refusal to enter the chamber because of a medical condition. Sixty children were recruited and randomly allocated to two groups. The 60 participants

were chosen from 90 children using a random number table in which the numbers 1–60 were generated by random sequence then divided into two groups according to their given numbers (even number = Group A and odd number = Group B). In each arm, participants were divided into five groups of six participants. The sequence of treatments was also randomised in order to further reduce any possibility of unblinding.

The allocation sequence remained concealed to all investigators, participants, parents, nursing staffs and all other clinical staff. All staff who participated in the pre- and post-study evaluations were banned from the hyperbaric facility during the interventions and had no access to the hyperbaric treatment record. Only the hyperbaric technicians, who had no input into the evaluation, knew the allocation of groups and individuals, and they were specifically instructed not to discuss the intervention nature or group assignments with anyone else. The effectiveness of the blinding process was estimated using parental surveys before and after the interventions.

During the first few sessions, one boy in the HBOT group dropped out because of his uncooperative behaviour during the intervention procedure, while another boy in the sham group dropped out following a febrile convulsion. The data from these two children were excluded from statistical analysis as it was considered that their inclusion on an intention-to-treat basis would not have any impact on the outcome analysis.

STATISTICAL ANALYSIS

All data were analysed using SPSS for Windows®, Version 12. Where appropriate, the data were tested for normality using the Kolmogorov-Smirnov Test. Interval scales were compared by independent Student t-test if normality was assumed and we planned to use the Wilcoxon Rank Sum Test in the absence of normality. Nominal scales were compared using chi-square test or Fisher's exact test, as appropriate. Before and after scores were analysed using the paired Student t-test and repeated measures ANOVA. Statistical significance was assumed if the *P* value for any comparison was < 0.05 (type 1 error).

Table 1
Baseline characteristics; differences between the hyperbaric oxygen (HBOT) and sham air groups not significant; means (SD) or actual numbers shown; clin. – clinicians ATEC – Autism Treatment Evaluation Checklist; CGIS – Clinical Global Impression of Illness Severity

	HBOT (n = 29)	**Sham air** (n = 29)
Age (yr)	6.10 (1.17)	5.67 (1.01)
Male/female	28/1	26/3
Risperidone	17	14
Other medications	19	16
Nutrition supplements	1	0
Current behavioural therapy	29	28
Total ATEC score (parents)	68.07 (25.43)	64.86 (22.80)
Total ATEC score (clin.)	60.21 (19.92)	60.55 (21.36)
Av. CGIS score (parents)	4.03 (1.05)	3.79 (0.98)
Av. CGIS score (clin.)	3.62 (0.78)	3.83 (0.93)

Results

Fifty-eight children, 54 boys and 4 girls (Table 1) completed 20 sessions of interventions. No serious adverse effects occurred. Only a few, minor-grade ear barotrauma events occurred in 2.6% of all HBOT sessions (15 of 580 HBOT, 11 of 29 children) and 0.5% of all sham sessions (3 of 580 HBOT, 3 of 29 children). No HBOT or sham air session was curtailed because of ear barotrauma or for any other reason.

BEHAVIOUR EVALUATION BY ATEC SCORES

The initial mean parental and clinician ATEC scores were not significantly different (parents $P = 0.615$; clinicians $P = 0.95$) (Table1). The average total parental ATEC scores decreased significantly after the interventions in both the HBOT and sham groups ($P < 0.001$ for both). Similarly, the average total clinician ATEC scores also showed significant reduction in both groups (HBOT $P = 0.015$; sham $P = 0.04$).

In the ATEC subscale scores, parents of those in the HBOT group indicated significant score reductions in three domains (sociability, sensory, and health), while parents of those in the sham group scored significant reductions in four domains (speech, sociability, sensory, health). Clinicians rated children in the HBOT group with significant score reduction in two domains (sensory and health), and in the sham group in three domains (speech, sensory, and sociability) (Table 2). There were no statistically significant differences in the average percentage changes of total ATEC score and all subscales scores when comparing the HBOT and sham groups, either by parents or clinicians.

CGI SCORES

There were no differences in initial mean parental and clinician CGIS between the groups (parents $P = 0.47$; clinicians $P = 0.42$) (Table 1). The mean parental CGIS score was significantly improved following HBOT ($P = 0.005$), but not sham air ($P = 0.1$), while there was no difference in the CGIS as indicated by the clinicians following either intervention (HBOT $P = 0.10$; sham air $P = 0.33$) (Table 3).

For the CGIC scores, the mean clinician score in the HBOT group was significantly lower than that in the sham group ($P = 0.03$), but not lower in the parental scores ($P = 0.28$). None of the children were rated by clinicians and parents as worse after the interventions (Table 3).

Table 2
Autism treatment evaluation checklist (ATEC) scores before and after trial, mean (SD); HBOT – hyperbaric oxygen therapy; ns – not significant

Outcome score and group	Pre-trial	Post-trial	*P* value
Parental ATEC scores			
Total score			
HBOT (*n* = 29)	68.07 (25.43)	58.31 (21.94)	0.001
Sham air (*n* = 29)	64.86 (22.80)	55.86 (24.93)	0.001
Speech			
HBOT	14.72 (6.34)	13.93 (6.15)	ns
Sham air	14.28 (6.35)	12.72 (6.76)	0.005
Sociability			
HBOT	15.83 (8.03)	13.45 (6.44)	0.014
Sham air	14.28 (6.84)	12.24 (6.84)	0.005
Sensory			
HBOT	16.76 (7.02)	14.83 (7.12)	0.027
Sham air	16.24 (5.93)	13.90 (7.03)	0.027
Health			
HBOT	20.24 (10.80)	16.76 (8.24)	0.025
Sham air	20.41 (10.18)	17.00 (9.43)	0.001
Clinician ATEC scores			
Total score			
HBOT	60.21 (19.92)	52.38 (19.11)	0.015
Sham air	60.55 (21.36)	52.93 (18.93)	0.004
Speech			
HBOT	14.66 (7.01)	13.66 (7.25)	ns
Sham air	15.24 (6.75)	13.93 (6.97)	0.006
Sociability			
HBOT	16.93 (6.40)	14.86 (6.52)	ns
Sham air	15.45 (7.03)	13.31 (4.58)	0.044
Sensory			
HBOT	16.31 (6.43)	13.93 (5.55)	0.027
Sham air	16.69 (6.96)	14.31 (4.86)	0.023
Health			
HBOT	13.45 (6.99)	10.79 (5.35)	0.026
Sham air	13.52 (5.98)	12.07 (6.93)	ns

Table 3
Parental and clinician Clinical Global Impression of Illness Severity (CGIS) and Clinical Global Impression of Change (CGIC) comparisons, mean (SD); HBOT – hyperbaric oxygen therapy; ns – not significant

Outcome score and group	Pre-trial	Post-trial	*P* value
Parental CGIS			
HBOT (*n* = 29)	4.03 (1.05)	3.69 (0.93)	0.005
Sham air (*n* = 29)	3.79 (0.98)	3.66 (0.86)	ns
Clinician CGIS			
HBOT	3.62 (0.78)	3.48 (0.78)	ns
Sham air	3.83 (0.93)	3.76 (0.83)	ns
Parental CGIC			
HBOT	–	2.34 (0.61)	ns
Sham air	–	2.55 (0.83)	
Clinician CGIC			
HBOT	–	2.31 (0.6)	0.03
Sham air	–	2.72 (0.8)	

PARENTAL SURVEY FOR EFFECTIVE BLINDING

Fifty-two percent of the parents whose children were in the HBOT group believed they would receive HBOT compared to 76% of those with children allocated to sham air and this difference was statistically significant ($P = 0.002$). There was an increased belief in both groups after 20 sessions (69% of HBOT group and 83% of sham air group parents, $P < 0.001$), indicating that blinding was successful.

Discussion

Hyperbaric treatment has been used for children with autism and has been reported as a successful intervention in several recent studies.[21,27] Only one of these reports was a randomised study, in which the partial pressure of oxygen was only 31.6 kPa in the 'treatment' group versus 21.9 kPa in the sham group and did not include an arm with 100% oxygen at hyperbaric pressures.[21] Good evidence to guide practitioners is, therefore, lacking.

In order to improve this situation, we have conducted a randomised, double-blinded investigation of true HBOT as a therapy in autism. While the clinicians, parents and participants were unaware of allocation, it was not possible to blind the hyperbaric technicians to therapy in the interests of safety. The high proportion of parents who believed their children had received true HBOT suggests blinding was successful.

Both the HBOT and sham air groups in this study showed significant improvements in overall behaviour after completion of 20 sessions of intervention, but HBOT failed to show any greater behavioural improvement when compared to sham air. Given the high proportion of parents who believed their children were receiving HBOT, this suggests that HBOT conferred no benefit above that owing to a participation (or placebo) effect. Although clinicians reported greater improvement in the CGIC sub-score and parents reported lower severity in CGIS sub-score after HBOT, the other sub-scores (clinician CGIS and parental CGIC) failed to show such improvements, and the importance of these findings are unclear.

These findings are interesting to compare with the previously reported trial in which a 38% improvement in the control groups who received slightly pressurised room air at 104 kPa was seen.[21] In our study, the sham group similarly received slightly pressurised room air at 116 kPa. There is no widely accepted theory for the mechanism by which either 'low pressure' air or slightly oxygen-enriched air would have a beneficial effect on the behaviour of these

children with neuro-developmental disorders. Interestingly, it has been shown that a pressure increment as small as 20 mmHg above 1 ATA decreased pro-inflammatory cytokines *in vitro* (including IL-1beta), that have been found in some children with autism.[28–30] However, this work involved 24-hour pressure exposure, and it is not known whether much shorter pressure exposures *in vivo* would have a similar effect. What is far more likely is that this is a participation or placebo effect. Considerably more evidence is needed before accepting there is a true rationale to support the routine use of low-pressure hyperbaric treatment in order to improve behaviour in children with autism.

While some unexplained biochemical mechanism may have been responsible for the improvements noted, there are a number of other possible interpretations. We observed both before and during the conduct of this study that parents of children with autism were desperately looking for help for their children. The stories of the successful use of HBOT in autism from previous reports were well circulated among these parents and were associated with high expectations for benefit. These parents eagerly searched for any slight improvement in their children. This positive attitude could have had an effect on themselves and how they treated their own child. By this reasoning, the scored responses in the sham air group might be related to their belief that the children were receiving HBOT. Furthermore, most of the participants continued their current therapies while undergoing our trial and the improvement could partly be a result of those interventions. Another possibility is that as a result of our study, these parents spent a significantly longer time than usual with their children on the days of intervention, and had increased opportunities to learn successful strategies both from each other and from the clinicians with whom they came into contact.

Conclusion

Children with autism who received 20 one-hour sessions of either HBOT at 153 kPa or sham air treatment at 116 kPa had significant improvements in overall behaviour. However, hyperbaric oxygen failed to show significant differences in behaviour improvement when compared to sham air. The improvements noted in both groups were not consistent between parents and the clinicians who were asked to evaluate the behaviours. Our study failed to show any clinically significant benefit from HBOT when compared to a sham air confinement in the hyperbaric chamber, and we cannot recommend the routine use of HBOT in this regard. Both interventions were considered safe and well tolerated.

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Conflict of interest

Mayuree Sampanthavivat is a board members of HM Queen Sirikit Naval Hospital, Royal Thai Navy Foundation who funded this research. The other authors report no potential conflict of interest.

Acknowledgements

This research was funded by HM Queen Sirikit Naval Hospital, Royal Thai Navy Foundation and was presented at the 17th International Congress on Hyperbaric Medicine, 2011. We would like to acknowledge Drs Fakjit Poonpol, Nareerat Kamonpakorn, Arom Kaewboonchu and Pasinee Taycharpipranai for study design and clinical evaluation, Prawin Yanapirak, Kaewta Kitkamhang, Wuttichai Banjongpru and the hyperbaric care team from the Division of Underwater and Aviation Medicine, Naval Medical Department for their hyperbaric care and technical control, Maneerat Narangsiya for data collection, and Pawinee Buranaraktham for manuscript preparation. The authors wish to express special thanks to Drs Michael Bennett and Simon Mitchell for reviewing this manuscript and offering valuable advice prior to submission.

Submitted: 08 February 2012
Accepted: 22 July 2012

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The database of randomised controlled trials in hyperbaric medicine maintained by Michael Bennett and his colleagues at the Prince of Wales Hospital Diving and Hyperbaric Medicine Unit, Sydney is now at:

<http://hboevidence.unsw.wikispaces.net/>

Assistance from interested physicians in preparing critical appraisals is welcomed. Contact Assoc. Prof. Michael Bennett: <M.Bennett@unsw.edu.au>

Monitoring carbon dioxide in mechanically ventilated patients during hyperbaric treatment

Asger Bjerregård and Erik Jansen

Abstract

(Bjerregård A, Jansen E. Monitoring carbon dioxide in mechanically ventilated patients during hyperbaric treatment. *Diving and Hyperbaric Medicine*. 2012;42(3):134-136.)

Background: Measurement of the arterial carbon dioxide (P_aCO_2) is an established part of the monitoring of mechanically ventilated patients. Other ways to get information about carbon dioxide in the patient are measurement of end-tidal carbon dioxide ($P_{ET}CO_2$) and transcutaneous carbon dioxide ($P_{TC}CO_2$). Carbon dioxide in the blood and cerebral tissue has great influence on vasoactivity and thereby blood volume of the brain. We have found no studies on the correlation between $P_{ET}CO_2$ or $P_{TC}CO_2$, and P_aCO_2 during hyperbaric oxygen therapy (HBOT).

Method: We studied 10 intubated and ventilatory stable patients during HBOT. End-tidal and transcutaneous measurements provided continuous data. Arterial blood samples were collected after reaching the operational pressure of 284 kPa (2.8 ATA) and analysed outside the chamber. A total of 17 paired samples of $P_{ET}CO_2$, $P_{TC}CO_2$ and P_aCO_2 were obtained.

Results: There was a good correlation between $P_{ET}CO_2$ and P_aCO_2 using linear regression ($r^2 = 0.83$). Bland-Altman analysis showed that $P_{ET}CO_2$ on average was 2.22 kPa higher than P_aCO_2 with limits of agreement (LoA) at ± 2.4 kPa. $P_{TC}CO_2$, on average, was 2.16 kPa lower than P_aCO_2 and the correlation using linear regression was poor ($r^2 = 0.24$). Bland-Altman analysis revealed LoA at ± 3.2 kPa.

Conclusion: During hyperbaric conditions we found that $P_{ET}CO_2$ as opposed to $P_{TC}CO_2$ offered the greater precision, but there was great variability among patients. Care must be taken when using $P_{ET}CO_2$ or $P_{TC}CO_2$ as an estimate of P_aCO_2.

Key words

Patient monitoring, carbon dioxide, hypercapnia, hyperbaric oxygen therapy, ventilators

Introduction

Monitoring carbon dioxide (CO_2) is vital during mechanical ventilation to prevent hypercapnia and cerebral vasodilatation. Hypercapnia is known to inhibit the normal autoregulation of cerebral blood flow resulting in vasodilatation. This increases the toxic effect of oxygen during hyperbaric oxygen therapy (HBOT) and the risk of seizures. Vasodilatation poses a specific risk in patients with cerebral oedema including carbon monoxide-poisoned patients who often have cerebral inflammation.[1–4]

The correlation between arterial carbon dioxide (P_aCO_2) and both end-tidal ($P_{ET}CO_2$), and transcutaneous carbon dioxide ($P_{TC}CO_2$) has been well established under normobaric conditions.[5–7] We have searched for similar studies performed during HBOT. However, no publications were found on the correlation between $P_{ET}CO_2$ and P_aCO_2 and only one study regarding the correlation between $P_{TC}CO_2$ and P_aCO_2.[8] The goal of this study was to determine alterations in carbon dioxide during HBOT and how $P_{ET}CO_2$ and $P_{TC}CO_2$ each correlate with P_aCO_2 under hyperbaric conditions.

Methods

SUBJECTS

This prospective observational study was performed at Rigshospitalet Copenhagen University Hospital; 10 consecutive, mechanically ventilated patients undergoing HBOT were included from January to March 2011. All data were obtained during routine clinical care. Retrospectively, the local ethics committee determined that additional informed consent was not required.

PROCEDURES

The study was conducted in a multiplace chamber equipped to handle a single intensive care patient. HBOT consisted of 90 minutes at 284 kPa (2.8 ATA). All patients were mechanically ventilated (Siaretron 1000, Siare, Italy) in volume control mode and monitored with a mainstream capnograph (M2501A, Philips, Holland). The first arterial sample was drawn a minimum of 20 minutes after reaching operational pressure and the second 30 minutes later. The samples were analysed at normobaric conditions (ABL700-series, Radiometer, Denmark) within 5 min of being drawn. The transcutaneous sensor (TCM4, Radiometer, Denmark), was placed in the mid-clavicular line, 5 cm below the right clavicle with a temperature of 44 +/-1^{O}C.

STATISTICAL ANALYSIS

Linear regression and Bland-Altman analyses were used to assess the correlation between $P_{ET}CO_2$ and P_aCO_2 and between $P_{TC}CO_2$ and P_aCO_2. In the latter, the limits of agreement are the mean difference ± 1.96 standard deviations.[9] Quantitative results were described by the mean and standard deviation (SD). MedCalc v. 11.2 was used to analyse the data.

Results

The 10 patients included were five women and five men, aged 40 to 79 years. Nine patients came from the intensive care unit and one from the trauma centre. Eight of the patients were treated for necrotising fasciitis and two for carbon monoxide poisoning. All patients were haemodynamically stabile. One patient required the use of vasopressors (noradrenaline 1 μg kg^{-1} min^{-1}). Patients were often treated with multiple sessions, of which only one was included in this study. In three of the patients, it was only possible to obtain a single arterial blood sample.

All patients were normocapnic upon arrival at the pressure chamber with P_aCO_2 at 4.94 (0.95) kPa. In one case it was necessary to increase the ventilation during treatment. In the remaining patients with unaltered respirator settings, the response to HBOT varied among patients as P_aCO_2 increased between 7% and 80% between the two arterial samples. In the 17 arterial samples obtained, P_aCO_2 was 6.2 (1.87) kPa.

During the first 10 minutes of HBOT, $P_{ET}CO_2$ increased between 62% and 151%, but after this initial increase the $P_{ET}CO_2$ remained stable until decompression. Using linear regression there was a good correlation between $P_{ET}CO_2$ and P_aCO_2 ($r^2 = 0.83$). Bland-Altman analysis showed that $P_{ET}CO_2$ overestimated P_aCO_2 by 2.22 kPa with limits of agreement (LoA) at ± 2.4 (Figure 1).

The transcutaneous readings were also stable after 10 minutes, but the response to HBOT varied among patients as $P_{TC}CO_2$ decreased in some patients and increased in others. In the Bland-Altman analysis $P_{TC}CO_2$ underestimated P_aCO_2 by 2.16 kPa with LoA at ± 3.2 (Figure 2).

Discussion

DEVELOPMENT OF HYPERCAPNIA

It seems that two mechanisms might cause hypercapnia in mechanically ventilated patients during HBOT: reduced expiratory flow and increased ventilatory dead space, V_{DS}. As pressure rises, so does the density of inspired air. This leads to an increase in airway resistance. The inspiratory flow is maintained by the ventilator by increasing the pressure, but the expiratory flow will inevitably decrease. This results in a prolonged time of expiration and favours ventilation at higher lung volumes, decreasing the compliance of the lungs, and possibly causing CO_2 retention. It has been demonstrated that V_{DS} increases by 18% at 284 kPa in a healthy subject at rest.[10] A worsening of the physiological mismatch between lung ventilation and perfusion is the most likely cause. If a corresponding increase in ventilation is not applied, CO_2 will increase. The wide variability in P_aCO_2 in patients under pressure could indicate that additional factors contribute to the hypercapnia observed during HBOT.

END-TIDAL MEASUREMENTS

That $P_{ET}CO_2$ consistently overestimated P_aCO_2 might be the result of a phenomenon termed 'cross-interference'.[11,12] The device analyses an infrared spectrum passed though the expired gas and analyses a narrow range of wavelengths, called the absorption spectrum, where the amount of light is reduced as the amount of CO_2 rises. Gases such as nitrogen, nitrogen oxide and oxygen have very similar absorption spectra and can interfere with that of CO_2. The increased ambient pressure widens the absorption spectrum of each gas causing an increased overlap with the neighboring gases, an effect called pressure broadening, which could cause

Figure 1

Bland-Altman plot of arterial carbon dioxide (P_aCO_2) and end-tidal carbon dioxide ($P_{ET}CO_2$); mean +2.2 kPa, limits of agreement ± 2.4 kPa.

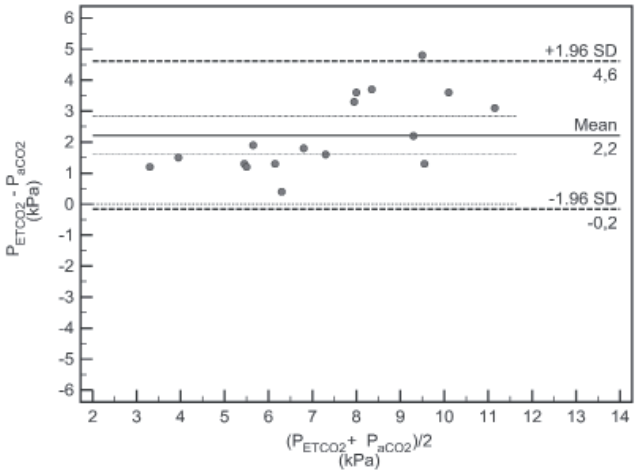
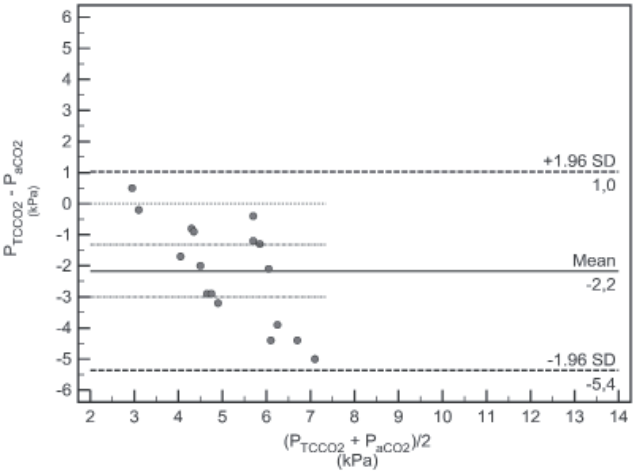


Figure 2

Bland-Altman plot of arterial carbon dioxide (P_aCO_2) and transcutaneous carbon dioxide ($P_{TC}CO_2$); mean -2.2 kPa, limits of agreement ± 3.2 kPa.



falsely elevated readings.[13] The devices used today are designed to minimise the effect of cross-interference, but are not developed specifically for hyperbaric use and therefore do not take into account the effect of pressure broadening.

TRANSCUTANEOUS MEASUREMENTS

Our findings suggest that $P_{TC}CO_2$ correlates poorly with P_aCO_2. Similar results have been reported elsewhere.[8] This is likely owing to physiological changes to the perfusion of the skin, and thereby the amount of CO_2. As an indicator of microcirculatory haemodynamics, $P_{TC}CO_2$ is an interesting parameter, but probably not one that can be expected to equal P_aCO_2, especially during HBOT.

Conclusions

Mechanically ventilated patients undergoing HBOT seem to be at risk of developing hypercapnia as P_aCO_2 increased by as much as 80% in some patients. The response, however, is highly individual, which underlines the need for precise estimates of P_aCO_2 during treatment. From the data gathered at 284 kPa, it seems that $P_{ET}CO_2$ overestimated P_aCO_2 on average by 2.22 kPa, but followed a linear regression model. $P_{TC}CO_2$ underestimated P_aCO_2 on average by 2.16 kPa and showed no linear correlation. Both methods for estimating P_aCO_2 can provide valuable information, but care must be taken when using such measurements to decide whether hypercapnia is imminent or present and changes in ventilation are required.

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Submitted: 18 March 2012
Accepted: 20 June 2012

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A review of 17 years of telephone calls to the Australian Diver Emergency Service (DES)

David Wilkinson and Steve Goble

Abstract

Wilkinson D, Goble S. A review of 17 years of telephone calls to the Australian Diver Emergency Service (DES). *Diving and Hyperbaric Medicine*. 2012;42(3):137-145.)

Introduction: The Diver Emergency Service (DES) in Australia provides specialised medical advice on diving incidents 24 hours a day to divers, dive operators, families and health professionals. It is operated from the Hyperbaric Medicine Unit of the Royal Adelaide Hospital where the physician-on-call also carries the DES phone (1800-088200 or +61-8-8212-9242).

Methods: Data from calls to the service have been compiled into a computer database since 1991. Calls for the 17 years from 1991 through 2007 were analysed.

Results: A total of 6,083 calls were logged, an average of 358 calls a year. Calls from Queensland and New South Wales each accounted for 25% of calls. Calls originating from outside Australia have been increasing and now make up 25% of calls. The diver themselves initiated the call 50% of the time and 66% of the calls were about male divers. The age range of divers was 12 to 95 years old. The mean age has increased from 30 to 36 years, with a greater proportion of calls from divers aged 50 years or older (from 2% to 14%). The largest group of calls (37%) related to whether symptoms might be the result of decompression illness (DCI). DCI was considered to be the probable diagnosis in 17% of calls, and possible in a further 12%. Other common findings were barotrauma (11%) and questions regarding fitness to dive (15%). Older divers were more likely to call in relation to a medical problem.

Conclusion: Interpretation of these data is qualitative but the prolonged collection period of 17 years allows some consideration of trends as to who calls the DES and why.

Key words

DES - Diver Emergency Service, incidents, injuries, fitness to dive, decompression illness, numbers, safety

Introduction

The Divers Emergency Service (DES) in Australia is a dedicated telephone number (1800-088200 or +61-8-8212-9242) offering specialised diving medicine advice 24 hours a day. It has operated since 1986 from the Hyperbaric Medicine Unit (HMU) of the Royal Adelaide Hospital. There has been a perception that the medical training of doctors in Australia does not adequately equip them to assess and manage many dive-related problems, and that this may have led to the compromised care of some divers. The mission of DES is to provide relevant and timely advice which will allow formulation of a management plan for an injury or health concern in a diver. Anyone can call DES; however, it is specifically targeted to the diving community and the medical field.

The financial costs have been kept to a minimum with the medical advice provided by the hyperbaric physician-on-call at the Royal Adelaide Hospital. However, there has always been a requirement to pay for the dedicated telephone handset and associated call costs. Initially, this money came from a government grant, various donations and from fund-raising activities undertaken by HMU staff. In 1993, the non-profit, dive safety organisation Divers Alert Network Asia-Pacific (DAN AP) offered to fund the service while maintaining access for the entire diving community.

The current system utilises a free-call number for calls made within Australia and a user-pays number for international calls. Calls are answered by the Communications Room of the South Australian Ambulance Service where basic details are gathered and any immediate advice provided. A pager alerts the physician on call to an incoming call, which is transferred to the phone held by the physician. A printed data sheet is used to record the information and any advice provided. This review is an analysis of 17 years of information recorded from 01 January 1991 to 31 December 2007.

Methods

On completion of the DES call, the data sheets are stored securely in the HMU. Monthly transcripts are received from the Ambulance Communication Room, which are reconciled with the information on the data sheets. Since 1991, this information has been entered into a database (Office Access 2003®; Microsoft Corporation, Redmond, Washington) and stored on a secure computer within the HMU.

Trends in the data were assessed for significance by linear regression and have been reported as scatter plots with regression line, the coefficient of determination (r^2) and probability value. Trend analysis and chi-squared test were performed using statistical software (Statistica version 6; Statsoft, Tulsa, Oklahoma). It was not possible to

Table 1
Origin of DES calls 1991 through 2007 (n = 6,083)

Origin of call	No of calls	%
Queensland	1647	27
New South Wales	1500	25
Victoria	685	11
South Australia	660	11
Western Australia	367	6
Tasmania	85	1
ACT	83	1
Northern Territory	80	1
Overseas	896	15
Unidentified	80	1

obtain specific consent from each caller for the use of this information; however, the reporting of de-identified DES data has been approved by the Research Ethics Committee of the Royal Adelaide Hospital.

Results

There were 6,083 logged telephone calls handled, an average of 358 calls per year (Figure 1). Figure 1 also shows the time of the day that the call was received (Australian central time). The total number of calls received from each state of Australia and from overseas is listed in Table 1. The decline in the number of DES calls over the review period can be attributed to a significant trend of fewer calls from Australia (Figure 2) with the numbers symmetrically reduced across all of the Australian states. In spite of this, there has been an increasing trend in calls from overseas (Figure 2) such that they now constitute about 25% of the annual total. A further 25% of calls currently originate from each of Queensland and New South Wales with the remaining 25% from the other Australian States and Territories. There were a total of 896 calls from outside of Australia. The bulk of these calls came from the very popular band of tropical dive locations to the north of Australia, stretching from Thailand in the west to Fiji in the east (Table 2). However, calls have come from almost every imaginable location including the Red Sea, Korea, Galapagos Islands and the Australian Antarctic Territory, and from commercial aircraft while in flight. Although the data are not illustrated, the southern states of Australia made fewer calls over the months of June to August, which corresponds to the winter months in the Southern Hemisphere. The overseas calls showed no variation over the course of the year and calls from Queensland showed only a mild dip over winter.

Table 2
Most frequent locations of overseas calls to DES (n = 896)

Origin of call	No of calls	%
Papua New Guinea	216	24
Indonesia	140	16
Thailand	89	10
Solomon Islands	73	8
Vanuatu	55	6
Fiji	52	6
Malaysia	52	6
All other locations	224	25

The caller is categorised in Table 3. Consistently about 50% of the calls originated from the diver themselves and about 2% of calls from the buddy. While a call from an instructor or divemaster usually indicates someone who had been in the water with the diver, a non-diving supervisor is considered to be someone with a responsibility for the activity but who had not been in the water at the time of the incident. This category includes dive shop owners, dive boat skippers and supervisors of commercial dive operations. There has been an increasing trend in calls from instructors and divemasters (Figure 3) and they currently make up about 20% of annual calls. There has been a decreasing trend in calls from physicians (Figure 3). In the early years over 30% of calls came from physicians but more recently they make up about 10%.

Table 3
Who called the DES phone line? (n = 6,083)

Caller	No. of calls	%
Diver	3029	50
Buddy	134	2
Physician	1177	19
Instructor/divemaster	499	8
Non-diving supervisor	200	3
Family/friend	321	5
Nurse	86	1
Other	637	10

Table 4
Summary of calls to DES about children ≤ 15 years (n = 77); DCI – decompression illness

Diagnosis	No of calls	Age range (yr)
Probable DCI	1	15
Possible DCI	13	12–15
Unlikely DCI	6	12–15
Ear barotrauma	7	13–15
Sinus barotrauma	3	12–15
Pulmonary barotrauma	1	14
Fitness-to-dive enquiry	22	7–15
Medical problem	9	2–15
Marine envenomation	7	3–14
Musculoskeletal/trauma	2	12, 13
Altitude post-dive	2	14, 15
Other	4	14–15

Figure 1
Number of DES calls and time received (Australian central time)

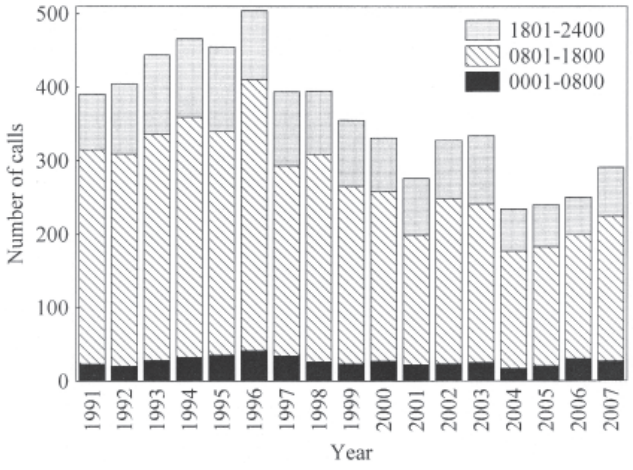


Figure 2
Trend in DES calls from Australia and overseas

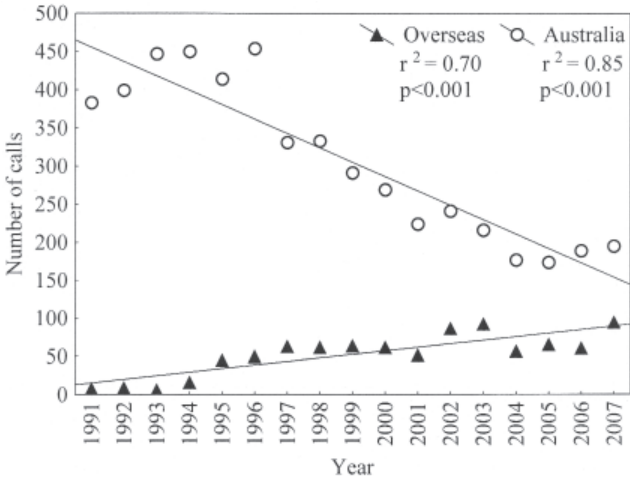


Figure 3
Trend in calls from instructors and physicians

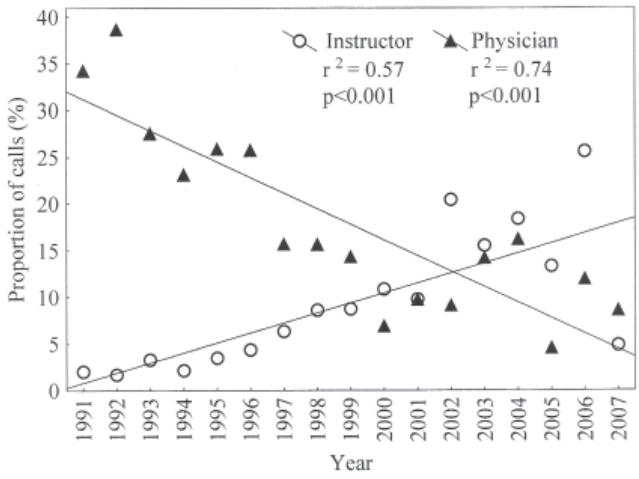
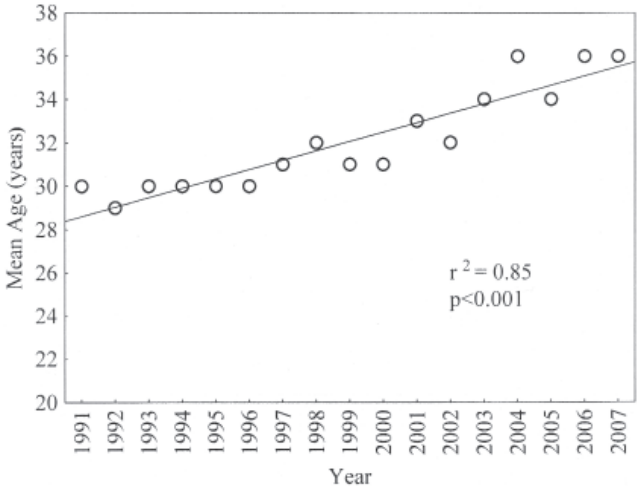
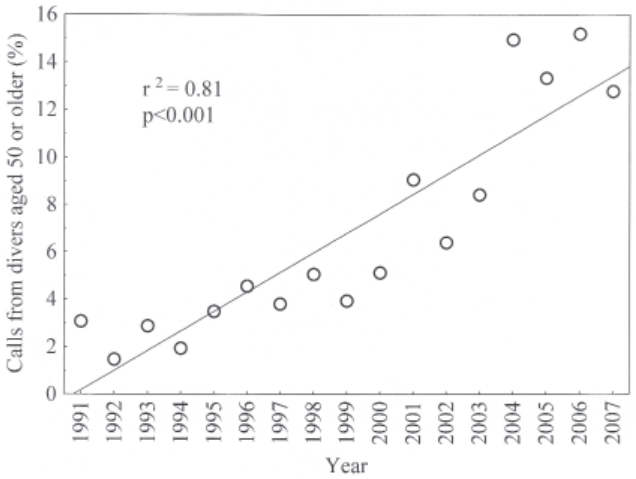


Figure 4
Age of divers calling the DES line, by year



The diver was male in 66% of calls, with a wide age range, from 2 to 95 years old. Some of the calls about children did not actually involve diving, such as the three-year-old with a marine envenomation while wading in water or the physician with a nine-year-old prospective scuba diver and a fitness-to-dive question. The youngest person with a diving problem was 12 years old; the 95-year-old was a scuba diver. Calls relating to children (15 years and younger) are summarised in Table 4. There has been a trend of increasing mean age of the diver (Figure 4), from 30 to 36 years. Also, the proportion of calls from divers aged 50 years or older has shown an increasing trend (Figure 5) from 2% to 14%. A total of 359 calls were from divers aged 50 years or older (6% of total).

Figure 5
Percentage of DES calls from divers ≤50 years, by year



The provisional diagnosis or reason to call is summarised in Table 5. There was a declining trend for fitness-to-dive questions (Figure 6) from over 30% to 15% currently. There was also an increasing trend in enquiries regarding

Table 5
Diagnosis/reason for call to DES; DCI – decompression illness (n = 6,083)

Diagnosis	No of calls	%
Probable DCI	1026	17
Possible DCI	732	12
Unlikely DCI	466	8
Barotraumas	664	11
Fitness to dive	844	14
Information	528	9
Follow up	267	4
Musculoskeletal	249	4
Medical	333	5
Marine envenomation	143	2
Dive related	242	4
Other	589	10

Table 6
Common symptoms and signs reported to DES line with probable decompression illness (n = 1,026)

Symptom	Number	%
Pain	595	58
Paraesthesia	551	54
Fatigue	295	29
Headache	200	19
Dizziness	177	17
Weakness	164	16
Nausea	147	14
Poor concentration	119	12
Skin rash	80	8
Visual disturbance	54	5
Loss of consciousness	39	4

Table 7
Calls to DES diagnosed as barotrauma (n = 664)

Site of barotrauma	No of calls	%
Middle ear	298	44.9
Inner ear	99	14.9
Sinus	147	22.1
Pulmonary	86	13.0
Mask	25	3.8
Dental	7	1
Suit	2	0.3

medical problems unrelated or incidental to diving (Figure 6), currently almost 10% of calls. Probable decompression illness (DCI) was diagnosed in 1,026 calls (17%), 689 males and 337 females. Cerebral arterial gas embolism (CAGE) was suspected in 70 calls (7% of probable DCI calls). The reported signs and symptoms of DCI are shown in Table 6. Multiple symptoms and/or signs were common. Skin rash was reported in 80 calls (51 males, 29 females; 8%) with an increasing trend to reporting a rash with probable DCI (Figure 7). Loss of consciousness was reported in 39 calls, with CAGE believed likely in 32. A rapid ascent was reported in 14 of the 32 calls. Barotrauma was diagnosed in 664 calls (11%) (Table 7).

The diagnosis or reason to call was compared for divers aged 50 or older to those younger than 50 years (data not displayed). There were very few differences in the diagnoses; however, there was a significantly higher proportion of calls related to a medical or non-diving issue in the older group of divers (13%) compared to the younger cohort (5%) (χ^2 (1, n = 6,083) = 31.00, $P < 0.001$).

Discussion

The primary role of DES has always been telemedicine. Telemedicine involves the use of information and communication technologies to deliver health care services,

Figure 6
Trend in calls to DES about fitness to dive and medical issues

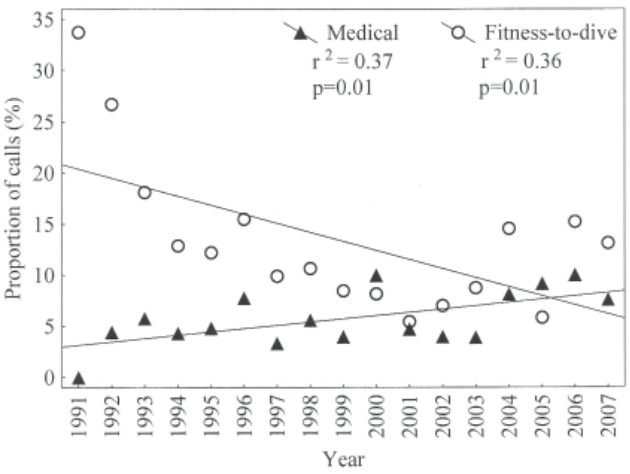
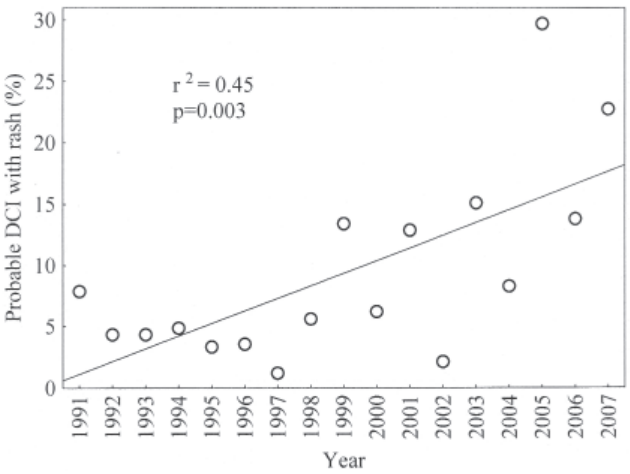


Figure 7
Trend of probable decompression illness (DCI) caases reporting skin rash to DES line



usually over a distance. While telemedicine is becoming increasingly sophisticated, with use of video facilities and even robotic surgery, DES provides a telephone-based service only. The advantage of this, however, is that anyone with a mobile phone can now access specialised medical advice in underwater medicine.

Independent of the telemedicine aspects, it was recognised early in the life of DES that there would be value in collating and analysing the information derived from these calls. This information creates a database of diving incidents that relates to the (usually immediate) health concerns in divers. Other diving incident databases do exist, and different methods of data collection will influence the information reported. For instance, the British Sub-Aqua Club (BSAC) publishes an annual diving incidents report.[1] Incidents are any unexpected dive events, not just medical problems. Divers are invited to complete a web-based form sometime after the incident with further contextual information sought, from which precipitating and contributing factors might be identified. The Divers Alert Network (DAN) publishes an annual report which describes the emergency calls made to their Medical Call Services Centre (DAN 'Hotline').[2] The Hotline operates as a telephone-based medical help service similar to DES, and the data from both more closely reflect the "*perspective of the first responder to an emergency*".[2]

As with any database of incidents, DES data are qualitative, not quantitative. Only data from those incidents that get reported will be collected. Also, there is no record of the denominator, or total number of dives taking place. Analysis of the data, therefore, will not allow calculation of the incidence or prevalence of specific events. However, it will highlight common problems and identify areas that might require further consideration. With 17 years of data to call on, consideration of trends into who calls the DES and why is possible.

CALLS – WHEN AND WHERE FROM?

Notwithstanding the qualitative nature of the DES data, the pattern of these calls does conform to what would be expected of a cross-section of diving activity. Two-thirds of the divers were male. Also, most of the calls came from Queensland and New South Wales, two states traditionally expected to account for a large proportion of the diving activity. On an annual basis, there was a consistent dip in calls from the southern states over winter months, when the cooler water temperature attracts fewer divers. This seasonal variation in calls can also be seen in the BSAC reports, given that the diving is in the United Kingdom.[1] BSAC found that, in 2010, 74% of the reports occurred during the summer months. If DES is accurately reflecting dive activity, then two trends in the origin of calls warrant discussion.

Firstly, a decreasing number of calls were made from within Australia over the period of the review (Figure 2). While the analysis does show a prominent decreasing trend (using linear regression admittedly), the scatter plot also suggests that the numbers may have reached a plateau in the last couple of years. This raises the often-debated consideration that fewer people are actively diving. Estimating how many dives have actually taken place is very difficult as one must rely on many assumptions. One paper suggested that the training agencies in Australia certified 54,153 new scuba divers in 1994 but only about 48,000 in 2007.[3] Other interpretations for the decline might be that fewer divers suffered injuries, whether through better training, safer dive practice, or that fewer people chose to use the service.

The other trend is the significant increase in overseas calls (Figure 2). The initial increase may be attributable to DAN AP's participation in 1993 and subsequently better advertising of the DES throughout the broader Asia-Pacific region. The steady rise since may be due to an increased awareness of DES (even though there were fewer calls from Australia at the same time) or an increase in the overall number of divers visiting these regions together with an increase in diving activity of the local population. Remote areas in the Asia-Pacific region offer divers the opportunity to dive in pristine, undeveloped environments. An increase in tourism trade and improved transport infrastructure within these countries now allows more divers to reach these locations. Unfortunately the improved access for tourists has not been matched by a commensurate improvement in the medical facilities available to them. This, in turn, highlights some of the difficulties DES has encountered when dealing with a problem in a remote location; the advising physician is heavily reliant on the quality of the telecommunication contact when attempting to collect accurate information, usually in the absence of examination findings and any knowledge of the medical support that is available locally and regionally. It seems that divers give more thought to the dive site when planning their trip than to the availability of appropriate medical services or to anticipating and preparing for the problems a dive trip might entail.

One change in recent years is the improved network of recompression chambers now available in the Asia-Pacific region, making consideration of aeromedical retrieval less common. Details of the location of regional recompression chambers are kept on file with the DES telephone. The increasing load of calls from divers looking for medical assistance while diving overseas, together with the sometimes limited medical options they have available to them, suggests this issue deserves more attention.

The catchment area served by the DES is large, stretching across Asia and much of the Pacific, encompassing many time zones. Calls have come from all corners of the world. Little can be interpreted from the time of the call and it usually bears no relationship to the severity of the problem. Some problems lead to immediate contact while other problems may be observed and contemplated for a period of hours, sometimes weeks.

WHO CALLS?

The diver made the call half of the time; however, it was surprising how few calls were made by the buddy: only 2%. While the sport always promotes 'buddy diving', the DES data suggest any involvement of the buddy evaporates once divers are out of the water. The role of the buddy certainly becomes less important with any delay in onset of symptoms and with the common recreational practice of diving as a group under the supervision of a dive instructor or divemaster. Although the divers may be 'buddied up', it is the instructor or divemaster who has overall responsibility for the group, prompting them to initiate contact with DES. Certainly there has been an increasing trend of calls from instructors and divemasters (Figure 3); on the other hand calls from the buddy have been consistently low throughout.

Many calls from an instructor or divemaster were made in the immediate post-dive period while still on board the dive boat, and usually indicated a problem with a rapid onset. A delay in onset or recognition of a problem may then lead to a call from a non-diving supervisor, such as the shop owner who learns of a problem only once the diver has returned to shore. Calls from a dive boat skipper were often from live-aboard vessels in far-flung locations using a radio telephone.

Calls from physicians have fallen over time (Figure 3). When you consider the similar reduction in calls about fitness-to-dive (Figure 6), especially from the earlier years when fitness questions made up 30% of calls, it can be understood that many of the calls from physicians were requesting help in determining whether a person was fit to dive. It is not within the capacity of the DES to determine fitness over a telephone consultation and this service is not encouraged. If the physician has had no experience with diving medicine, DES may be able to suggest where the diving candidate could be referred, based on the Diving Doctor List compiled by the South Pacific Underwater Medicine Society. However, for the physician with training in underwater medicine who is seeking specific advice, DES can be a useful resource to help develop a management strategy for a diver with a complicated medical issue.

In 2005, DES collaborated with DAN AP to publish a poster warning of the symptoms and signs of DCI and advertising the DES phone number. This was mailed to as many emergency departments as possible that were near coastal regions of Australia. It was intended to be displayed in the staff areas to prompt physicians to consider the possibility of a dive-related medical problem. Consequently, the nature of the calls from physicians has changed over time, with fewer fitness-to-dive questions and more calls from doctors working in emergency departments wishing to discuss the significance of a problem in a diver they are assessing.

A small but intriguing number of calls have come from the spouse, partner, family member or friend of the diver. Most of these were people who were not present when the diving took place but became aware of a problem later on, sometimes not until the diver returned home. Their concern about the well-being of their loved one prompted them to call, seeking guidance. This group was not evident in early years but currently make up about 10% of calls. It is unclear how they became aware of the DES; perhaps the diver suggested it while being reluctant to call himself? More than one call has been initiated by a concerned partner searching through the diver's paperwork to find DAN AP documents with the DES number displayed (personal communication). Regardless of who initiates the call, experience has demonstrated that there is no substitute for talking directly to the diver and this has become standard DES practice. The story of the incident can change dramatically once it becomes second- or third-hand.

WHAT WAS THE PROBLEM?

Based on the information gathered over the telephone, a diagnosis was proposed in most cases. This diagnosis must be considered provisional as it is usually made based only on the history, sometimes second-hand and often without access to any physical examination. However, a good history has generally been very reliable in diagnosing many dive-related problems. It should also be remembered that DES is an advisory service only and is not in a position to accept responsibility for ongoing medical management or to demand that those at the scene take a particular course of action. As a consequence, DES may not be informed of the final diagnosis if medical review is obtained. While these considerations could question the reliability of the DES diagnosis, feedback has been received in many cases and this has confirmed that the provisional diagnosis has generally been accurate or appropriate. Assessment of the reliability of a diving telemedicine service was described recently by the Swiss chapter of DAN, who run their own hotline.[4] They compared the severity of the hotline assessment of DCI with clinical assessment and found the consistency to be good.

Prudence and common sense are required in recommending a medical review. The margin for error in making a diagnosis over the telephone means that the threshold for recommending a review must be set low, but will be influenced by many factors. These factors include: likelihood of the diagnosis, clinical significance of the diagnosis, what local medical services are available and the distance to more comprehensive medical services. Whether the diver actually proceeds to the review depends on another set of factors including geographical location and insurance status.

The provisional diagnosis for the DES call (Table 5) is comparable to the dive injury data in the DAN Annual Diving Report.[2] For the calendar year of 2007, DAN received a total of 2,505 emergency calls (most of which came through the DAN Hotline). They report a working diagnosis of DCI in 26%, barotrauma in 26%, non-diving related problem in 14%, envenomation in 6% and trauma in 2%.

Decompression illness

The most frequent reason to call the DES was a concern that symptoms could be indicative of DCI. If symptoms could be confidently attributed to another diagnosis, such as musculoskeletal injury, the call was listed under that category. Otherwise, the calls were stratified into three groups based on likelihood of the DCI diagnosis: probable, possible and unlikely DCI. Unlike the Swiss approach,[4] there were no set criteria for making the distinction between these; all aspects of the information provided were used to make a determination, and this ultimately relied on the clinical impression of the DES physician taking the call and recording the information. Collectively these groups accounted for 37% of all calls.

Not surprisingly, the most common symptoms reported in DCI cases were pain and paraesthesia (Table 6). The 2008 DAN report from the USA described 53 cases of skin decompression sickness (12% of 424 DCI cases) and interestingly found a gender bias – 60% of these were female.[2] The DES data does not accord with this; the probable DCI category was male in 67% and skin rash with DCI was male in 71%, suggesting no gender bias. While the true incidence of rash is unknown, it is interesting to speculate on why the DES data suggest an increasing trend in skin rash. This period of time has seen a dramatic shift towards the use of dive computers rather than tables (anecdotal). Computers allow a change in dive pattern away from the square dive profile, towards multi-level diving, which permits multiple ascents and descents, longer periods underwater and shorter surface intervals. The dive activity may be influencing the way the body handles an inert gas load and its distribution in body tissues.

DAN reported that 5% of the DCI group were thought to have CAGE.[2] This is comparable to data from DES calls (7%) and cases presented both with and without loss of consciousness. The classic presentation of CAGE involves a rapid ascent by the diver and loss of consciousness on surfacing. Loss of consciousness is a dangerous event; if it occurs while the diver is still in the water there is a high likelihood of drowning. About half of the cases diagnosed as CAGE presented with loss of consciousness, and only half of these reported a rapid ascent. This means that the classic presentation for CAGE was found in only one quarter of calls thought to be CAGE and serves as a reminder that CAGE may present in other ways and, importantly, may not present with loss of consciousness.

Barotrauma

Almost half of the barotraumas reported were thought to be of the middle ear, while sinus barotrauma was also very common. Several calls each year described mask barotrauma, typically in the less experienced diver for whom the startling appearance of subconjunctival haemorrhage was quite alarming even though it was usually not uncomfortable.

Pulmonary barotrauma involves alveolar gas finding its way into other anatomical sites. If the gas passes into local tissues, then symptoms may reflect pneumothorax or pneumomediastinum, and it will likely be diagnosed as pulmonary barotrauma. If the gas passes into the blood stream, the ensuing neurological manifestations will mean a diagnosis of CAGE (with or without pulmonary barotrauma).

DAN made the observation that their data of several years ago were provided by hyperbaric facilities describing the divers that presented to them.[2] Not surprisingly, hyperbaric facilities were seeing many more cases of CAGE than pulmonary barotraumas; this led to a public perception that CAGE was far more common. The DAN report, which now draws its data from the emergency calls made to the DAN Hotline, lists more calls diagnosed as pulmonary barotrauma (52 calls) than CAGE (23 calls). The DES data reveals a similar experience, with 86 calls diagnosed as pulmonary barotrauma and 70 calls as CAGE. Of course, neither of these data sources will provide an incidence of the problem; however, the numbers suggest that we should be thinking more about pulmonary barotrauma. This also highlights how data can be biased by how, where and when they are collected.

Fitness to dive

Fewer calls have come from physicians seeking an answer to their fitness-to-dive questions. More recently, calls were initiated by the diver when confronted by a change in their own health status. Examples of the sort of questions encountered include how long to lay off diving after surgery for a hernia operation or the consequence of a change in antihypertensive medication. DES may not be able to provide a clear answer but would suggest how to achieve it. This may include a recommendation to seek a formal dive medical examination from a suitable physician. Fitness calls currently make up almost 15% of the annual total and indicate a demand by divers for medical advice specific to their own situation.

Information

Information calls (9%) often related to requests for directions to diving medical services or questions of a general nature about DCI. Many calls related specifically to the recommended time between diving and flying. This can then become problematic (for the diver) when a public address announcement in the background of the phone call indicates that the diver has already arrived at the airport but had then become anxious about the interval between their last dive and the impending flight.

Follow up

Follow-up calls included a diver reporting what had happened since the last call (such as response to normobaric oxygen in someone with suspected DCI), and a courtesy call

to inform us of the progress of a diver handed over to other medical services (such as retrieval).

Musculoskeletal injury

Diving is a physically demanding activity, even when out of the water. Lifting and carrying heavy tanks on a moving boat will inevitably lead to soft-tissue and bony injuries. While some cases of trauma were obvious, in others the pain came on after a dive with no obvious precipitant and presented with a query whether the pain could be from DCI. This can be difficult to assess over a telephone consultation and soft-tissue injury was diagnosed only when the physician was confident of such. Features that might be helpful in discriminating between a soft-tissue injury and pain due to DCI include other symptoms of DCI, a recognised event leading to injury, localised tenderness to palpation and any features that make the pain better or worse.

Medical

There was a modest upwards trend in calls about medical conditions that were independent or incidental to the dive (Figure 6), which may be attributable to the increasing proportion of calls from older divers (see below). Medical calls included many viral illnesses and gastrointestinal problems; ischaemic heart disease was also common.

Envenomation

Some years ago, the DES number was regularly published in first-aid books as the Marine Stinger Hotline, and DES still receives a number of calls each year related to marine envenomation. Jellyfish injuries were common and ciguatera was considered likely in a number of calls from the Pacific Islands. Several calls have come from people who keep bullrouts at home and should be more careful of their spines when cleaning the aquarium. Immersion of fish-spine injuries in hot water has been spectacularly successful in relieving pain, especially in remote locations where no medical services are available. For expert advice, the Australian Venom Research Unit offers emergency telephone consultation to physicians and paramedics only (1300-760-451).

Other dive-related problems

Other dive- or marine-related calls included headache, rapid ascent without symptoms, salt-water aspiration and drowning, skin rash (not DCI), sea sickness and gas contamination.

The young diver

The minimum age for scuba diving is a controversial topic with dive physicians holding conflicting opinions. DES does not determine fitness to dive; however, we do believe better injury data are required in this area. There appears to be less controversy about divers 16 years or older, so this review will only look at the 77 calls regarding children aged 15 years or younger (Table 4). Six calls (including the infants) involved non-divers with five marine envenomations while wading in water and one carbon monoxide exposure. There were 22 fitness-to-dive calls, usually from physicians. The majority of these involved a history of asthma; however, there were several calls about attention deficit hyperactivity disorder. For calls about actual scuba divers, ear barotrauma was a common event as were other medical conditions (usually infections and illnesses, but included one caller with acute asthma post-dive). Of concern are the 13 cases of possible DCI and one probable DCI. The outcome of these calls is not known to DES but would be of great interest.

The ageing diver

Anecdotally many dive clubs and people in the dive industry have observed that the active dive population appears to be getting older. The DES data reveals that the average age of the diver has increased by six years over the 17 years of this review, with an increasing numbers of calls from divers aged 50 years or older. DAN reported that the mean age of the DAN membership base increased by six months for every year between 2000 and 2006.[2] With increasing age comes the risk of age-related medical illness and potentially an increase in risk with activities like scuba diving. The BSAC report notes that 47% of the 2010 fatalities involved divers over the age of 50 while this age group only represented 16% of the diving population.[1] DES has found that this older diver group is two-and-a-half times more likely than other age groups to call about a medical problem. The increasing influence of this older group is most likely the reason for the modest, increasing trend in medical calls in the overall data. This issue is becoming more prominent and, perhaps, calling the DES phone is leaving it a bit late.

Many of these calls were diagnosed as myocardial problems; a number were actual cardiac arrests requiring resuscitation. Not all of them occurred at the same time as the dive. Three important observations to be made are:

- There is a need for action on fitness to dive in the older diver. It has been difficult to persuade recreational divers of the importance of a medical review of fitness beyond their original dive medical, with a general reliance on personal motivation or family pressure to achieve this. Peer pressure could be applied by a pro-active response from dive training agencies, dive shops and dive clubs to promote the message that a dive medical should be revisited as the diver ages. Legislation requiring a fitness-to-dive review would be very complicated to enforce; it would be better for the dive community to own the problem.
- The older diver should prepare in advance for the increased chance of having to deal with a medical emergency on a dive trip. Ensure personnel at the destination are appropriately trained and any equipment

and medications are checked and permitted on an aeroplane and to enter a foreign country, if required. Consideration should also be given to the availability of local medical services. Everyone should have insurance that covers evacuation and dive injury treatment.

- The medical emergency may not happen during the dive and may occur at any time. Personnel and equipment need to be readily accessible.

Conclusions

DES offers diving medicine advice 24 hours a day by telephone. The collected data over a 17-year review are qualitative, but do reflect diving activity with a preponderance of male divers, most calls from Queensland and New South Wales and a seasonal variation in calls from southern Australian states. Increasing numbers of calls came from overseas, pointing to a need for divers to consider the appropriateness of medical services in remote locations.

The most common reason to call was to ask if symptoms could be the result of DCI (37%). Barotrauma was also common (11%). Divers have shown a desire for specialised medical advice that is specific to their needs and this has accounted for many of the calls about fitness to dive (14%) and information (9%). DCI can manifest with myriad symptoms and signs but the increasing trend of skin rash in probable DCI cases is unexplained.

There was an increase in the average age of divers calling DES, along with an increase in calls from divers aged 50 years or older. While they do report a largely similar range of problems, the older divers were more likely to report a medical problem unrelated or incidental to their diving activity. In junior scuba divers, commonly reported issues related to asthma and ear barotrauma. The outcome of several potential DCI cases is unknown.

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Acknowledgements

The success of DES has been the result of the efforts of many, not least of whom the physicians of the Hyperbaric Medicine Unit of the Royal Adelaide Hospital, over many years. Special thanks go to DAN AP for financial support and to the Communications Room staff of the South Australian Ambulance Service.

Submitted: 17 January 2011
Accepted: 24 June 2012

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Lower risk of decompression sickness after recommendation of conservative decompression practices in divers with and without vascular right-to-left shunt

Christoph Klingmann, Nils Rathmann, Daniel Hausmann, Thomas Bruckner and Rolf Kern

Abstract

(Klingmann C, Rathmann N, Hausmann D, Bruckner T, Kern R. Lower risk of decompression sickness after recommendation of conservative decompression practices in divers with and without vascular right-to-left shunt. *Diving and Hyperbaric Medicine*. 2012;42(3):146-150.)

Introduction: A vascular right-to-left shunt (r/l shunt) is a well-known risk factor for the development of decompression sickness (DCS). No studies to date have examined whether divers with a history of DCS with or without a r/l shunt have a reduced risk of suffering recurrent DCS when diving more conservative dive profiles (CDP).

Methods: Twenty-seven divers with a history of DCS recommended previously to dive more conservatively were included in this study and retrospectively interviewed by phone to determine the incidence of DCS recurrence.

Results: Twenty-seven divers performed 17,851 dives before examination in our department and 9,236 after recommendations for conservative diving. Mean follow up was 5.3 years (range 0–11 years). Thirty-eight events of DCS occurred in total, 34 before and four after recommendation of CDP. Four divers had a closure of their patent foramen ovale (PFO). A highly significant reduction of DCS risk was observed after recommendation of CDP for the whole group as well as for the sub-groups with or without a r/l shunt. A significant reduction of DCS risk in respect to r/l shunt size was also observed.

Discussion: This study indicates that recommendations to reduce nitrogen load after DCS appear to reduce the risk of developing subsequent DCS. This finding is independent of whether the divers have a r/l shunt or of shunt size. The risk of suffering recurrent DCS after recommendation for CDP is less than or equal to an unselected cohort of divers.

Conclusion: Recommendation for CDP seems to significantly reduce the risk of recurrent DCS.

Key words

Decompression sickness, decompression illness, patent foramen ovale (PFO), risk, risk management

Introduction

A right-to-left shunt (r/l shunt), caused predominantly by a patent foramen ovale (PFO), is a well-known risk factor for the development of decompression sickness (DCS). First described more than two decades ago, many studies have been published subsequently confirming an increased risk of DCS for divers who have a r/l shunt.[1–9] A 1998 meta-analysis calculated that the risk of developing severe DCS in the presence of a PFO increased by a factor of 2.52 and for any DCS by a factor of 1.93.[10] The risk of a major episode of DCS is directly related to the size of the septal defect.[9]

The presence of a PFO has been accepted as a risk factor for the occurrence of stroke and transient ischaemic attacks (TIA) in young patients, particularly if associated with an atrial septal aneurysm.[11] PFO closure is increasingly performed for the prevention of recurrent stroke or TIA as well as for the prevention of recurrent DCS in divers' on an individual basis.[12–18] However, a recent randomised controlled trial failed to show superiority of PFO closure over best medical treatment for preventing recurrent stroke or TIA.[19] On the other hand, a Swiss working group has recently published good evidence that PFO closure significantly reduces the risk of developing DCS, even though one diver with PFO closure still suffered neurologic DCS.[20] However, there are no consensus guidelines to support this indication in divers.[3]

To our knowledge, no studies have evaluated the influence of reduced inert gas load during diving in divers with or without a r/l shunt and with a history of DCS. For this reason we performed follow up on divers examined in our department for the presence of a r/l shunt with a history of DCS to assess their risk of recurrent DCS after we had provided advice and education on how to reduce nitrogen load when diving.

Methods

The Ethics Committee at Ruprecht-Karls University in Heidelberg, Germany approved this study (Project Number S-030/2008) and all participants gave their written consent. Forty-nine divers with a history of physician-confirmed DCS from previous studies and from our diving medical clinic were contacted.[7,21–23] Having received written consent, a structured telephone interview was conducted using a purpose-designed questionnaire which included health and general diving-related questions and specific questions about history of DCS, recurrent DCS, and whether PFO closure was performed.* DCS was classified as being either 'minor' or 'major'. Minor DCS symptoms included 'bends', cutaneous lymphoedema and cutaneous erythema with or without extreme fatigue, headache and nonspecific

* The questionnaire may be obtained from the authors: <info@tauchersprechstunde.de>

dizziness. Major DCS events were defined by one or more of the following symptoms: severe vertigo; limb weakness; cutaneous sensory level; impaired bowel or bladder control; paresis or paraplegia; blurred vision; dysarthria; amnesia for the event, hemiplegia or loss of consciousness after a dive. To reduce the risk of false-positive diagnosis of DCS, symptoms must have persisted for at least 30 minutes and have occurred within 24 hours of the dive. Number of logged dives, symptoms of DCS, number of DCS events and PFO status (i.e., closure procedure) were recorded.

All divers had received either a transcranial or carotid Doppler sonography to screen for a vascular right-to-left shunt (r/l shunt), either as a participant of one of our previous studies or as a patient in our clinic. A r/l shunt was diagnosed as small when five or more air microbubble signals occurred in the Doppler spectra of either middle cerebral artery or carotid artery after the Valsalva manoeuvre. The r/l shunt was classified as large if more than 20 signals were detected, in accordance with our previously published classification system.[7,24] After confirmation of DCS and confirmation of PFO status, all divers were educated to perform any future diving using 'conservative' dive profiles (CDP). At the time of examination of the divers who took part in our earlier studies, there had not been a formal recommendation for divers to practice CDP, as exists today.[25,26]

Recommendations for CDP included: use of nitrox, but with decompression times calculated on air tables; no dives deeper than 25 metres' sea water (msw); no repetitive dives; minimising Valsalva manoeuvres, no decompression dives and a 5-minute safety stop at 3 msw. These recommendations were not obligatory and divers were free to choose their individual nitrogen-reducing methods. Even though we recommended all divers with a history of DCS at the time of presentation to dive conservatively in the future, we cannot be sure whether the divers adopted this advice or not.

STATISTICS

The 'risk of DCS' was calculated by division of DCS events by the number of logged dives multiplied by a factor of 10,000 for easier presentation of the otherwise very small values. Statistical analysis was performed with SAS Version 9.1® (Cary, USA). A Wilcoxon signed-rank test was performed for the comparison of the median of two related samples (risk of DCS before and after recommendation for CDP). The significance level was defined as $P \leq 0.05$ and highly significant when P was ≤ 0.01. The absolute risk for DCS before and after recommendation for CDP was compared using confidence intervals. Risk of DCS per diver before and after recommendation for CDP was compared using a McNemar test. Box-and-whiskers plots were generated for graphical presentation of the results of both groups according to the definition of Tukey: the box represents the upper and lower quartile, the centre line represents the median and the vertical lines represent the whiskers.[27]

Results

Of 49 divers who were examined after DCS for presence of a r/l shunt and whom we tried to contact, 32 divers (65%) gave their written consent to take part in this study. Telephone interview revealed that five divers had stopped diving after their examination in our institution, leaving 27 divers in this survey. Twenty male divers and seven female divers with an average age of 47 years (range 31–65 years) performed in total 27,087 dives, 17,851 before examination in our department (median 400, range 60–2,600), and 9,236 after recommendation for CDP (median 200, range 60–2,400) respectively. Time between examination in Heidelberg and the telephone interview varied between 0 and 11 years (mean 5.3 years). Thirty-eight incidents of DCS occurred in total, 34 before recommendation for CDP and four in three divers after recommendation for CDP. Twenty major and seven minor DCS events occurred in the first group and three major DCS events in the second group. After receiving a recommendation to dive using CDP, 17 divers used enriched air nitrox as a breathing gas, three divers used trimix and seven divers used air as their breathing gas.

R/L SHUNT

On examination, nine of the 27 divers had no demonstrable shunt, nine had a small and nine a large r/l shunt.

After examination in our department and before telephone interview, four divers, two with a small and two with a large shunt, had undergone closure of their PFO. Three divers had PFO closure immediately after examination in our institute and one diver had PFO closure after she had two episodes of neurological DCS. After PFO closure, no further DCS events occurred in any of the four divers. Owing to the small sample size no statistical analyses were performed on this group. Further, all four divers who had PFO closure were excluded from statistical evaluation of DCS risk before and after recommendation for CDP as, after PFO closure, they no longer met the inclusion criteria for a r/l shunt.

DCS RISK BEFORE AND AFTER RECOMMENDATION FOR CDP

The absolute risk of suffering DCS before examination in our department for the remaining 23 divers was 0.002 or 20/10,000 (events of DCS / dive). After examination in our department and recommendation for CDP the absolute risk of suffering DCS was 0.0003 or 3/10,000 (events of DCS/ dive). The absolute risk difference for DCS before and after examination was 0.0017 or 17/10,000 (95% confidence intervals, 0.0009 to 0.0025). As the confidence interval does not include zero the risk reduction is significant with a relative risk reduction of 85%.

It is also appropriate to consider the risk per diver of suffering DCS. Before examination in our department, 23 divers had one or more DCS events. After recommendation for

Figure 1
Box plots of DCS risk before and after advice on reducing nitrogen loading during diving with respect to the presence or absence of a patent foramen ovale; DCS risk – DCS events per 10,000 dives multiplied by 10,000

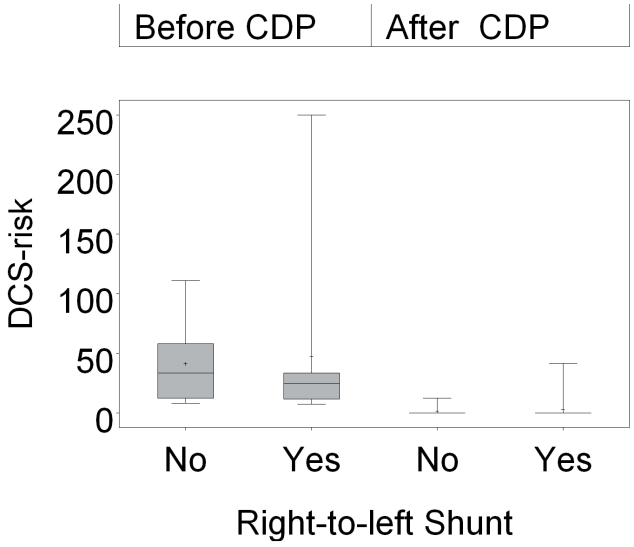
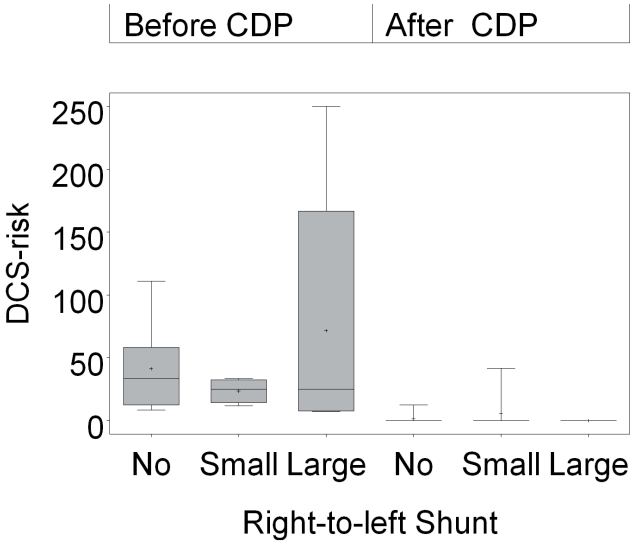


Figure 2
Box plots of DCS risk before and after advice on reducing nitrogen loading during diving with respect to right-to-left shunt size; DCS risk – DCS per 10,000 dives multiplied by 10,000



CDP, only two divers suffered one episode of DCS. Using the McNemar test, this difference is highly statistically significant ($P < 0.001$).

R/L SHUNT

Of the 23 divers who did not have a PFO closure, fourteen divers had a r/l shunt (seven small and seven large r/l shunts) and nine divers had no shunt. The mean DCS risk (multiplied by a factor of 10,000) for divers without a shunt was 41.3 (range 8.0–111) compared to 47.6 (range 7.4–250) for divers with a shunt. After the recommendation of CDP the risk lowered to 1.4 (range 0–12.5) for divers without a shunt and 3.0 (range 0–41.7) for divers with a shunt. This difference was highly significant in both groups ($P = 0.008$ and $P < 0.001$ respectively (Figure 1).

R/L SHUNT SIZE

The mean DCS risk for divers without a shunt was 41.3 (range 8.0 to 111) compared to 23.5 (range 11.8–33.3) for divers with a small shunt and 71.6 (range 7.4–250) for divers with a large shunt. After recommendation of CDP the risk reduced to 1.4 (range 0–12.5) in divers without a shunt, 6.0 (range 0–41.7) in divers with a small shunt and zero in divers with a large shunt. The DCS risk decreased in a highly significant manner after recommendation of CDP in divers with no shunt ($P = 0.008$) and significantly in divers with small or large r/l shunt ($P = 0.031$ and $P = 0.016$ respectively, Figure 2).

Discussion

Although many institutions recommend reduction of nitrogen load or decompression stress to prevent recurrent DCS it is surprising that no studies have been performed to substantiate the success of these recommendations.[25,26] The same applies for recommendations for divers with a r/l shunt. In the 1990s, when a r/l shunt was identified to be a risk factor for DCS, many diving medical specialists promoted a routine examination of divers in order to exclude a shunt. As a result of further studies, it became clear that even though the risk for DCS is increased with a r/l shunt, it remains quite small and the recommendations to screen for a r/l shunt have vanished.[10]

When DCS has occurred, especially after so called 'undeserved' cases of DCS, divers are encouraged to seek screening for a shunt. If a shunt is revealed in a diver who had 'undeserved' neurological DCS, some diving medical societies classify these divers as ineligible to scuba dive.[26] There are also several diving medical specialists who recommend divers with a history of DCS and a positive r/l shunt to undergo closure if it turns out to be a PFO, even though there is no clear evidence to indicate that this intervention reduces the risk of DCS or neurologic events.[16–19]

However, in a 2011 study of 83 scuba divers with a history of DCS and a follow up of 5.3 years, 28 divers had no PFO, 25 had a PFO closure and 30 continued diving with a PFO without closure.[20] At the beginning of the study there were no significant differences between the groups in the number of dives, dive profiles, diving depth or cumulative dives to more than 40 msw. After follow up, whilst there were no differences between the groups in respect to minor DCS events, the risk for major DCS was significantly higher in the divers with PFO and no closure than in divers with PFO

closure or divers without PFO. Although this offers new evidence that PFO closure reduces the risk for major DCS, the authors do not recommend closure in all divers with a history of DCS but rather recommend further studies to confirm these results.

In our study, only four divers underwent PFO closure and these remained free of DCS events thereafter in 1,436 dives. The group size and number of logged dives are insufficient to draw any conclusions about this intervention. In the 14 divers with a PFO but no closure, advice on reducing nitrogen loading simply resulted in an significant absolute risk reduction in DCS incidents. A similar, highly significant reduction in risk was also seen in the nine divers without a shunt. Even when the data were stratified by shunt size, and despite smaller group sizes, the differences remained significant. These data strongly suggest that recommendations for CDP, or possibly simply having had a previous DCS event, results in highly reduced risks of suffering recurrent DCS. Interestingly, the DCS risk after recommendation for CDP in both divers with or without a PFO was less than or equal to the risk of unselected cohorts of divers.[28,29] This outcome requires further study.

Our study has several limitations. Firstly, this is a small retrospective study of divers who were recruited from previous studies conducted at various times. The response rate (32 of 49) from divers whom we attempted to contact was satisfactory, given the extensive time period covered, and only five of these divers had ceased diving. Secondly, although the diagnosis of DCS was confirmed by a diving medical specialist, the divers were not examined by us at the time of their acute presentation with DCS and reporting bias is possible. Thirdly, examination for a r/l shunt was performed by more than one examiner and two techniques were used. Therefore, it is possible that the prevalence of r/l shunt may differ between groups as well as the r/l shunt size. Fourthly, there was no control group that continued to dive without any recommendations to change their diving habits. Finally, it is not possible to be certain that the divers from this study applied CDP.

Whether the risk reduction was as a result of our recommendation or the divers changed their diving habits independently of our recommendations after their first incident of DCS, it remains compelling that there are impressive risk reductions for DCS following the initial incident and counselling. A causal relationship has not been established in this study in the absence of a control group that continued diving without changed diving habits. Despite the limitations of our study, we would encourage hyperbaric units that treat diving accidents on a regular basis to commence a prospective study to address this issue. Given the large risk differences we observed, the study groups could be relatively small and it should be feasible to perform a controlled randomised study, with results from our study being used to inform the relevant power calculation.

Conclusion

We observed a highly significant reduction of DCS risk after providing divers with recommendations for conservative dive profiles (CDP), whether or not they had a r/l shunt. After recommendations for CDP, the risk of suffering recurrence of DCS was smaller than or equal to that of an unselected cohort of divers. Nevertheless, because of the heterogeneity of our small study population we cannot make general recommendations. A prospective, randomised study is needed to confirm our preliminary observations and to provide further information towards the reduction of risk for recurrent DCS.

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Acknowledgements

We thank Gary Smerdon, DDRC, Plymouth, UK for assistance with preparing the manuscript and helping us with the language. The results of this study were presented at the 2nd tri-national scientific meeting of the Austrian (ÖGTH), German (GTÜM) and Swiss (SUHMS) diving medical societies in Regensburg, March 2011.

Submitted: 31 July 2011
Accepted: 17 June 2012

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Provisional report on diving-related fatalities in Australian waters 2007

John Lippmann, Douglas Walker, Christopher L Lawrence, Andrew Fock, Thomas Wodak and Scott Jamieson

Abstract

(Lippmann J, Walker D, Lawrence CL, Fock A, Wodak T, Jamieson S. Provisional report on diving-related fatalities in Australian waters 2007. *Diving and Hyperbaric Medicine*. 2012;42(3):151-170.)

Introduction: An individual case review of diving-related deaths reported as occurring in Australia in 2007 was conducted as part of the on-going Divers Alert Network (DAN) Asia-Pacific dive fatality reporting project.

Method: The case studies were compiled using reports from witnesses, the police and coroners. In each case, the particular circumstances of the accident and details from the post-mortem examination, where available, are provided.

Results: In total, there were 19 reported fatalities, comprising three females and 16 males. Nine of the deaths occurred while snorkelling and/or breath-hold diving, eight while open-circuit scuba diving, one while using a closed-circuit rebreather, and one while using surface-supply breathing apparatus. Cardiac-related issues were thought to have contributed to the deaths of at least three but possibly up to six snorkel divers and possibly two scuba divers. One diver is believed to have died as a result of immersion pulmonary oedema of diving. Six of the compressed-gas divers were very inexperienced, three being certified within 14 days prior and dying while under the guidance of an instructor.

Conclusions: Inexperience, pre-existing medical conditions and buoyancy issues were highlighted in several deaths in this series.

Key words

Diving deaths, scuba, breath-hold diving, surface-supply breathing apparatus (SSBA), closed-circuit rebreather, diving accidents, case reports

Introduction

Although some diving-related fatalities are almost certainly unavoidable, many deaths might have been avoided through better education, greater experience, good medical screening and advice, better equipment choice or design and common sense. The aim of the Divers Alert Network (DAN) Dive Fatality Reporting Project (incorporating Project Stickybeak) is to educate divers and the diving industry and to inform diving physicians on the causes of fatal dive accidents in the hope of reducing the incidence of similar accidents in the future and of detecting, in advance, those who may be at risk. This report includes the diving-related fatalities between 01 January and 31 December 2007 that are recorded on the DAN Asia-Pacific (AP) database. When a fatal accident is unwitnessed, it is often difficult to determine exactly what has occurred. In such cases, we have sometimes included considered speculation within the comments to provoke thought about the possible sequence of events.

Methods

As part of its on-going research into, and reporting of diving fatalities in Australia and elsewhere in the Asia-Pacific region, DAN AP has obtained ethics approval from the Human Research Ethics Committee, Department of Justice and Government of Victoria, Australia to access and report on data included in the Australian National Coronial Information System (NCIS). The methodology used for this report is identical to that described previously for the 2004 Australian diving-related fatalities.[1]

Snorkelling and breath-hold fatalities

BH 07/01

This 39-year-old, overseas male tourist was in a group tour of the Great Barrier Reef (GBR). He had no history of medical problems, was not taking any medications and was believed to be healthy and a reasonable swimmer. He had not snorkelled before, and during the trip to the reef the group was given a talk on snorkelling, followed by a DVD presentation. Although he apparently spoke some English, the victim appeared not to pay attention. There was also a brochure available in the victim's native language.

The victim was provided with a Lycra suit, mask, snorkel and fins, and offered a life jacket to wear, which he accepted. However, he had difficulty getting into the life jacket as it appeared to be too small, so the tour guide/snorkel instructor helped him to zip up the jacket – the victim needed to exhale in order to do so. The weather was reported to be fine and the water relatively calm. After a short swim in the shallow water, during which the group appeared to manage well, they were allowed to join others in the patrolled swimming area with deeper water, overseen by a lifeguard. There were reported to be about 70 swimmers in the area under the watch of a single lifeguard.

Table 1
Summary of snorkelling and breath-hold diving-related
BMI – body mass index; BNS – buddy not separated; BSB – buddy separated before problem;

ID	Age	Gender	Height (cm)	Weight (kg)	BMI (kg m^{-2})	Training	Experience	Dive group
BH 07/01	39	M	182	96	29.0	nil	nil	GSB
BH 07/02	15	M	173	95	31.7	nil	some	BSD
BH 07/03	33	M	174	142	46.9	n/s	n/s	BSB
BH 07/04	44	M	170	87	30.1	n/s	some	GSB
BH 07/05	51	M	169	81	28.4	nil	nil	GSB
BH 07/06	37	M	178	60	18.9	nil	nil	solo
BH 07/07	63	M	166	68	24.7	nil	some	BSB
BH 07/08	70	F	150	56	24.9	n/s	n/s	GSB
BH 07/09	38	M	180	87	26.9	n/s	n/s	BNS

After an estimated five minutes since the group entered the area, the lifeguard noticed the victim floating face-down and motionless approximately 30 metres from shore and away from the other swimmers and being carried out with the current. When he paddled to him on his rescue board, he found the victim to be unconscious and apnoeic, still wearing snorkelling equipment and floating face-down supported by the life jacket. The lifeguard delivered two rescue breaths before dragging the victim to shore where he again gave some rescue breaths. Basic life support (BLS) was commenced with ventilations delivered using a bag-valve-mask. An automated external defibrillator (AED) was attached but no shock was advised, indicating that the victim was likely to have been in asystole. Advanced life support (ALS) was later implemented by a helicopter rescue paramedic but the victim failed to respond and was pronounced dead at the site.

Autopsy: The body had early decompositional changes. The victim was obese (body mass index (BMI) 29 kg m^{-2}). The right and left lungs weighed 705 g and 702 g respectively and were described as congested. The heart weighed 436 g and was described as normal. The report is light on detail – there is no description of pulmonary oedema nor whether the lungs appeared over-expanded and histology was obscured by autolysis. Toxicology revealed a blood alcohol of 0.72 g L^{-1}. The cause of death was given as drowning. The elevation of blood alcohol was believed to have contributed to the drowning.

Comments: Given this was an unwitnessed and apparently silent death the exact mechanism of the accident is unknown. However, it appears that the victim's life jacket was far too small for him and this, combined with his obesity, would have restricted his chest compliance and breathing and hampered his ability to snorkel safely. It would certainly have been more difficult for him to clear the snorkel if he was unable to take a deep breath. The blood alcohol level detected would have been consistent with impaired judgment and may have slowed his response to inhalation of water.

Others in the group later complained that their instruction and supervision was inadequate, and this could well have been the case as the supervisor had several distractions. The victim's apparent lack of attention to the initial briefing could have been, among other things, an indication of poor comprehension. Although it is appreciated that other supervisors were in the vicinity, the ratio of one lifeguard to directly oversee around 70 snorkellers seems inadequate. Although the life jacket provided buoyancy, it failed to support the unconscious victim with his face out of the water. This is an important function of a life jacket (and arguably of a scuba diver's buoyancy compensator, BCD).

Summary: Apparently healthy overseas tourist; reasonable swimmer; first use of snorkel; constrictive life jacket; water too deep to stand; blood alcohol level 0.72 g L^{-1}; among large crowd in supervised swimming area; drowning

BH 07/02

This obese but otherwise healthy, 15-year-old male was spearfishing for octopus with two friends as they had done on many previous occasions. After about two hours, one swam back to shore with some of their equipment while the other two continued to snorkel 30 to 50 metres from the shore. The

Table 1 (cont)
fatalities in Australian waters in 2007
BSD – buddy separated during problem; GSB – group separated before; n/s – not stated

Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Weights (kg)	BCD	Disabling injury
recreation	n/s	surface	n/s	n/s	worn	asphyxia
spearfishing	4	n/s	n/s	n/s	n/s	asphyxia
spearfishing	n/s	surface	n/s	n/s	n/s	cardiac
recreation	n/s	surface	n/s	n/s	n/s	asphyxia?cardiac?
recreation	n/s	surface	n/s	n/s	nil	cardiac
recreation	n/s	surface	n/s	n/s	n/s	asphyxia
recreation	n/s	n/s	n/s	n/s	n/s	asphyxia?cardiac?
recreation	n/s	surface	n/s	n/s	n/s	ashpyxia?cardiac?
recreation	n/s	surface	n/s	n/s	n/s	cardiac

victim fired his spear at an octopus and found the spear had become embedded under a rock and would not come free. He then used the thin line attached to the spear to get extra leverage by wrapping it round his right hand. His buddy saw him struggling under the water, kicking his legs. Neither the victim nor buddy in the water had a knife with them as the only knife the group had was with the third diver who had returned to shore. The buddy attempted without success to release the line and pull the spear free, then called for help to people on the beach, swimming closer to shore in order to be able to guide them. It took them a short time to find the victim, who was about two metres underwater. They cut him free from the line which had entangled him and took him ashore where ambulance officers provided ALS, without success. He had been submerged for approximately 10–15 minutes.

Autopsy: There were bruises and abrasions on the right hand and fourth and fifth fingers consistent with entanglement with the spear-gun line. The right and left lungs weighed 605 g and 740 g respectively and were partially collapsed. There was frothy fluid and diluted blood in the trachea and bronchi, and pulmonary oedema and congestion in the lungs. The findings were consistent with drowning, modified by extensive resuscitation efforts (collapse, not overexpansion). The cause of death was given as drowning due to entanglement by speargun line while snorkelling.

Comments: This tragic accident indicates the potential dangers of entanglement when snorkelling or diving and the importance of having a knife readily available. The buddy tried valiantly to free his friend but was unable to because he had no knife to cut the line.

Summary: Healthy teenager; spearfishing for octopus; spear fouled, so wrapped line around hand to free it and became entangled; buddy unable to release him as no knife available; drowning

BH 07/03

This 33-year-old, morbidly obese male had suffered a mild CVA eight years earlier, although there were no further details of his medical history other than that he had suffered from a dry cough for several weeks before the incident. He was not currently taking any medications and had appeared to be well and in good spirits. His previous snorkelling experience was not reported. He was with a group of relatives on an unpatrolled beach of a small bay. Shortly after lunch, he and two others decided to go snorkelling to spearfish and entered the water from a rock ledge. The victim was dressed in board shorts and was carrying a speargun and wearing mask, snorkel and fins. There was a moderate swell.

After a very short time his companions heard some yelling and saw their friend standing in the water, supported by two men. He looked unwell and was heard to say "*my time is up*" shortly before he became cyanotic and collapsed. He was brought to shore where BLS was commenced by one of his rescuers. The victim regurgitated some stomach contents, including his recent lunch. The ambulance arrived a few minutes later and found the victim to be apnoeic and pulseless. A defibrillator was attached and indicated that he was in asystole. ALS was implemented but was unsuccessful.

Autopsy: The pathologist described him as obese (BMI 46.9). The heart weighed 410 g with left ventricular hypertrophy of

16 mm (normal < 15 mm). The coronary circulation showed left dominance with a small right coronary artery, greater than 80% luminal narrowing of left main coronary artery and up to 70% narrowing of the left circumflex coronary artery. The aorta showed patchy atheromatous changes. The histology of the heart muscle showed equivocal early ischaemic changes but no old scarring. The lungs weighed 330 g and 390 g respectively, and were described as congested and a little heavy. There was a little frothy fluid in the trachea. The cause of death was given as cardiac arrhythmia due to ischaemic heart disease. Other contributing factors included terminal drowning and obesity.

Comments: The victim was at a high risk of cardiac-related death whether or not he went snorkelling. However, the combination of the exercise of swimming soon after having eaten appears to have triggered a cardiac event. Compared to the previous cases reviewed in this paper, the lungs are not particularly heavy and it is likely that heart disease is more significant than the drowning.

Summary: Previous CVA; morbidly obese; unknown snorkelling experience; separated from buddies; distress soon after entering water; severe cardiovascular disease; cardiac arrhythmia

BH 07/04

This 44-year-old, male tourist was with three friends on a charter boat on the GBR. His medical history was unknown but he stated that he was a strong swimmer and had some previous snorkelling experience. He appeared to be healthy and reported that he had no medical problems.

About 20–25 minutes after breakfast, which included a shot of 'jagermeister' (an alcoholic beverage), the victim took a ginger-based seasickness tablet (Travelcalm®), and with two friends and a snorkel supervisor donned mask, snorkel and fins and entered the water. The depth was about 4 msw, the sea had a small surface chop and there was negligible current. The group was snorkelling approximately 30 m from the boat when the skipper entered the water shortly afterwards to join the group. One of the tourists remained on board as a surface watch. The victim was then seen to be snorkelling back towards the boat, occasionally lifting his head to see where the boat was. He did not appear to be distressed. However, when he tried to board the boat he fell back into the water and the friend on board held out a fishing rod for him to hold onto, which he initially did. The skipper observed this and quickly swam to the victim but found him face-down in the water, unconscious and cyanotic.

When he was brought aboard, the victim was apnoeic. When the skipper rolled him into the recovery position, some stomach contents were drained, together with a small amount of water. The skipper then began BLS, assisted by the victim's friend, while alerting the others. BLS was continued for 10–15 minutes until staff from a nearby dive vessel arrived with oxygen equipment and an AED. The latter was attached and reported that no shock was advised. BLS was continued without response for another 17 minutes until a doctor advised by telephone that it be ceased.

Autopsy: The autopsy revealed bilateral aspiration pneumonitis with gastric contents in the upper airways and lungs which showed an early neutrophil reaction (suggesting that the aspiration occurred sufficiently long before death for the body to mount a vital reaction). The right and left lungs weighed 522 g and 533 g respectively. The heart weighed 352 g (normal) with coronary arteries showing less than 20% narrowing by atherosclerosis. The liver weighed 1,917 g and showed fatty changes. Toxicology returned a negative reading for alcohol. It was suggested that the victim possibly aspirated water through his snorkel and this could have resulted in arrhythmia. The cause of death was given as aspiration pneumonitis with fatty liver as a contributing factor.

Comments: Drowning should be considered as a possible alternative cause of death. Aspiration pneumonitis with a vital reaction is most uncommon where a diver has died at the scene although aspiration during resuscitation efforts is relatively common. A vital reaction usually takes minutes to hours to develop. What caused the aspiration in this case is unclear. Heavy recent alcohol consumption is associated both with fatty liver and paroxysmal arrhythmias (so-called 'holiday heart'). The latter are usually atrial in origin, although sometimes ventricular and associated with increased dispersion of QT intervals.[2] However, in this case, toxicology for alcohol was negative despite the recent reported consumption, although the presence of a fatty liver may well be a marker of long-term high alcohol consumption. It would seem unlikely that the victim could have suffered a significant aspiration prior to becoming unconscious but not appeared distressed before attempting to board the boat. Therefore, this would appear to support the hypothesis of aspiration-induced arrhythmia as the most likely primary event.

Summary: Apparently healthy; strong swimmer; no prior signs of distress; collapsed when trying to board boat; minimal cardiovascular disease; arrhythmia?, drowning?

BH 07/05

This 51-year-old, overseas, male tourist was an experienced swimmer but had never snorkelled before. He was described by his wife as fit and active, exercised daily and had seen his doctor recently. He had a history of oral cancer 3–4 years prior, gout, hypertension, and hyperlipidaemia. He was taking lisinopril 10 mg, allopurinol 100 mg, and simvastatin 40 mg daily. On the night before the accident, he had consumed a number of alcoholic drinks including a bottle of wine, two vodkas and a Cointreau.

The victim was on a day trip to the GBR on a large vessel. During the outward trip passengers were given a talk on snorkelling and its potential risks, told there would be some current at their destination, and offered floatation aids. The site was a moored pontoon with a roped area which was under constant watch. Because of the current, it was decided to have a tender outside the roped area to ensure rapid response to any problems. This was in addition to the lookout on the pontoon. The sea was described as calm and clear but there was a current moving away from the pontoon.

The victim donned a Lycra suit, mask, snorkel and fins and entered the water with a fellow passenger but then swam away from him. After about 30 minutes, the lifeguard in the tender watching the crowd of snorkellers from outside the roped area initially saw the victim about 10 metres away swimming easily in the direction of the current before changing direction back towards the pontoon. After he had swum about six strokes, later described as wild and ineffective, the victim saw the tender and raised a hand as if requesting assistance. When the tender reached him, he was asked to hold onto it. His head then tilted to one side and he became unconscious. The tender driver grabbed the victim's arm but was unable to pull him into the tender until he was assisted by several of the snorkellers. The victim was rapidly brought back to the pontoon where he was apnoeic and pulseless, so BLS was commenced. Supplemental oxygen (O_2) was provided, and when an AED was attached, four shocks were advised and given as ventricular fibrillation was detected. After consulting the Royal Flying Doctor Service, the trained crew, assisted by a passenger who was a nurse, administered four 1 mg ampoules of adrenaline down an oropharyngeal airway after attempts to establish an intravenous line were unsuccessful. Resuscitation was discontinued after 65 minutes, on radio advice by a doctor.

Autopsy: The autopsy revealed an overweight man (BMI 28.4) with extensive rib fractures and a perforation of the right ventricle, the result of resuscitation attempts. The heart weighed 390 g and showed 90% stenosis of the right and left coronary arteries and patchy interstitial fibrosis, but no description of acute ischaemia on histology. There was severe coronary arterial atherosclerosis, with almost complete loss of lumen in the anterior interventricular and right coronary arteries. Cardiac arrhythmia due to ischaemic heart disease was given as the cause of death. There was no history of heart disease but there was a history of hypertension and hypercholesterolaemia. The right and left lungs weighed 903 g and 1,004 g respectively, and were oedematous and congested consistent with terminal drowning.

Comments: This case highlights the reality that snorkelling deaths due to pre-existing health problems can be unavoidable despite well-controlled snorkelling situations and with rapid and appropriate first aid. This victim appears to have got into difficulties when he exerted himself trying to swim against the current. The combination of exertion, facial immersion and probable salt water aspiration (common with inexperienced snorkellers) are likely to have precipitated a cardiac arrhythmia in a heart predisposed to this. The dive operator's vigilance and preparedness are to be commended. Cardiac perforation is an uncommon complication of resuscitation and suggests over-vigorous resuscitation.

Summary: Apparently fit; being treated for hypertension and hyperlipidaemia; first snorkel experience; current; signalled for help; sudden death; unrecognised severe ischaemic heart disease with identified risk factors; cardiac-related death

BH 07/06

The victim was a 37-year-old, overseas, male tourist visiting the GBR. There is no record of his medical history but he appeared to be healthy. He was described as a poor swimmer and it appears unlikely that he had snorkelled before. He and his girlfriend hired mask, snorkel and fins and went snorkelling off an unpatrolled island beach. The weather was clear, the water relatively calm and there was a slight breeze. The couple snorkelled together for a while until the girlfriend returned to shore, leaving the victim to snorkel alone. About 15 minutes later, he was noticed floating unconscious in the water and eventually brought to shore by a nearby boat. The rescue took around 15 minutes, during which no BLS was provided, but it was commenced once he had reached the beach. The victim was then brought aboard a ferry and BLS was continued during the 45-minute journey to the mainland where an ambulance was waiting. When assessed, he was unconscious, apnoeic and in asystole. He was intubated and adrenaline was administered, briefly precipitating ventricular fibrillation which, after defibrillation, converted to a pulseless electrical activity. BLS was given during the transfer to hospital where he eventually died from the delayed effects of inhalation of seawater.

Autopsy: The right and left lungs weighed 1,269 g and 1,293 g respectively, and appeared congested. There was copious fluid on sectioning with large amounts of pulmonary oedema fluid in the trachea and bronchi consistent with drowning. The heart weighed 340 g and was normal. The cause of death was given as drowning.

Comments: This case once again highlights the importance of snorkellers being capable of swimming and of the need for close supervision of inexperienced snorkellers.

Summary: Apparently healthy; poor swimmer; probable first use of snorkel; separation; found unconscious 15 minutes later; delay to BLS; drowning

BH 07/07

The 63-year-old, male victim was described as "*fit as a fiddle*" by his daughter. He was an experienced snorkeller although "*not a strong swimmer*". He was with a friend who

was making her first snorkel swim. They entered shallow water together and he showed her how to snorkel, returning to the shore twice while she was getting used to it. On the third occasion, after a short time he ceased holding her hand to allow her to snorkel unassisted. She intended to remain close to the shore but when she found herself further out than she felt comfortable with, she looked around for him before returning to shore. She was alarmed by her failure to see him and notified the police. When the police and ambulance searchers found him, he was wedged between two rocks 'near shallow water' and was estimated to have been submerged for 30–40 minutes. He was unconscious, very cold and had no palpable pulse. It appears that the attending paramedics did not attempt resuscitation before/while transferring him to hospital, where he was pronounced dead.

Autopsy: The autopsy report notes abrasions over both hips and the top of his head (which could have occurred post mortem), but there were no signs of scalp bruising or significant trauma. The heart weighed 310 g, with widely patent coronary arteries. The only abnormality was a degree of mitral valve prolapse. Occasional small foci of ischaemic fibrosis were identified in the heart on histology, suggesting some form of heart disease, although this is not typically associated with mitral valve prolapse. The right and left lungs, weighing 780 g and 690 g respectively, were over-expanded and contained pulmonary oedema fluid. The upper airway contained foamy fluid, consistent with drowning. The cause of death was given as drowning with a possible contribution from mitral valve prolapse.

Comments: The coroner 'found' the cause of death to be drowning but omitted to make any comment on why this fatality occurred. Unfortunately, it was not stated whether any equipment had been lost, at what depth the victim's body was found or how his body was wedged in the rocks. There was also no mention of the sea conditions or water temperature: all factors that can be useful when investigating a dive fatality. It is noted that the victim was a weak swimmer. It is unclear whether he came into contact with the rocks before or after becoming unconscious. One could speculate that he lost equipment when washed against rocks or became trapped in the rocks and was unable to surface for air. It is also possible that he suffered from a cardiac arrhythmia related to the mitral valve prolapse, drowned and then became trapped. However, it is equally possible that the mitral valve prolapse was irrelevant.

Summary: Apparently fit; weak swimmer with some snorkel experience; separation; found wedged under rocks; mitral valve prolapse of unknown significance; drowning (cardiac-related?)

BH 07/08

This 70-year-old, overseas, female tourist had no significant medical history and was said to have been a strong swimmer. It is not known if she had snorkelled before. She took an unknown seasickness medication an hour before setting off by boat to a nearby island on the GBR. She and some family members decided to go snorkelling from the beach in a supervised area, despite her complaining of feeling dizzy. The weather was clear with a light wind and the sea was relatively calm. After a few minutes, the victim's companions noticed that she was missing and notified the lifeguard. Approximately 15 minutes later, an island staff member found the victim's body partly submerged and removed her from the water. BLS was commenced by the lifeguard and continued for 20–30 minutes, without success.

Autopsy: The upper airways showed foamy material. The right and left lungs weighed 525 g and 508 g respectively. The lungs showed peripheral displacement of air by central fluid, the appearances being typical of 'wet' drowning. The heart weighed 232 g and revealed a 60% concentric narrowing in the left anterior descending coronary artery (LAD). Histology revealed some haemorrhage into the plaque, as well as microscopic foci of ischaemic fibrosis. The cause of death was given as drowning with possible contribution from 60% stenosis of the LAD.

Comments: The scenario of this silent death is suggestive of a cardiac-related episode. Typically a 75% stenosis is usually required to cause death. However, consideration should be given to cardiac dysrhythmias when an unstable atheromatous plaque with haemorrhage in it and microscopic scarring due to ischaemia are present during exercise. The victim was feeling dizzy before entering the water and the effects of immersion and salt-water aspiration through her snorkel could have magnified the problem and caused her to become unconscious and drown.

Summary: Apparently healthy; strong swimmer; unknown snorkelling experience; seasickness medication; felt dizzy before snorkelling; silent death; moderate CVD; drowning (possibly cardiac-related)

BH 07/09

The victim, a 38-year-old male, was an overseas national working on an island in the north-west of Australia. Before being employed in Australia, he passed a medical check with no evidence of adverse health factors apart from being a pack-a-day smoker. His BP was 128/76 and he was moderately overweight (BMI 26.9). It is unknown if he had snorkelled before. The victim and three workmates decided to snorkel on a reef in a cove. He was wearing shorts, a mask, snorkel and fins. The water conditions were choppy, with a one-metre swell and a slight current. They entered the water from shore and, after only a few minutes, the victim indicated to his nearest buddy that he was having trouble breathing and coping with the sea conditions. He began to panic, lifted his mask onto his forehead and appeared to have difficulty swimming. The buddy swam to him and began to

assist him to swim towards shore, about 40 metres distant. The victim became increasingly panicky and lost his mask, snorkel, and one fin. The other workmates came over and assisted but, shortly before reaching shore, the group was briefly submerged by a large swell. On reaching shore, they found the victim to be unconscious, apnoeic and pulseless. A bystander began BLS, which was only continued for five minutes before being abandoned because of lack of response.

Autopsy: The autopsy revealed an unstable plaque in the LAD with a 90% stenosis and 50% stenosis of the right coronary artery. The heart weighed 430 g and showed no macroscopic scarring. The right and left lungs weighed 1,002 g and 854 g respectively, and were congested and oedematous. There was pulmonary oedema in the upper airways consistent with terminal drowning. The cause of death was given as ischaemic heart disease due to unstable plaque in the LAD.

Comments: It is likely that exertion triggered a cardiac arrhythmia in a man with an unrecognised critical stenosis of a coronary artery. Panic, loss of mask and snorkel and probable aspiration of seawater probably all contributed to the cardiac problem and resulted in terminal drowning, which would make resuscitation more difficult.

Summary: Heavy smoker; no history of ill-health; unknown snorkelling experience; difficulty with sea conditions; substantial atheroschlerosis; drowning (likely cardiac-related)

Scuba diving fatalities

SC 07/01

This 45-year-old woman had an undeclared history of attention deficit disorder for which she was prescribed dexamphetamine. She was apparently healthy and had become certified as an open-water diver one week earlier. She was now participating in an advanced open-water course and had completed three uneventful dives on the previous day to a maximum depth of 7 msw.

On this day, the weather was overcast; the water was calm and clear with visibility of 10–15 metres, and the dive was at slack water. The victim was with a group of six students, accompanied by an instructor and a divemaster. They descended to a depth of 26 msw and knelt on the seabed while writing their names backwards on a slate. The victim then gave a 'low air' hand signal. The instructor saw that her contents gauge read 120 bar and gave her his 'octopus' regulator to breathe on briefly while he breathed on her demand valve to check that it was OK, which it appeared to be. She then took back her own regulator. However, a short time later, she again signalled 'low air' before starting to ascend. The instructor immediately signalled for the others to remain on the seabed with the divemaster and caught hold of the victim by her BCD. They then ascended together while using his buoyancy to control their ascent rate. He noticed she seemed to be having some difficulty with her breathing, taking short, shallow breaths. However, she refused the offer of his secondary regulator. The ascent was described as controlled and at a rate of around 15 msw min^{-1}.

On surfacing, the instructor asked if she was OK to which she replied "*No, I don't feel good*" before rolling onto her side unconscious. Shortly afterwards, white froth began to flow from her mouth. The instructor then towed the victim to shore, some 30 metres distant, intermittently providing rescue breaths, despite the continued flow of frothy sputum. Another diver assisted the victim onto the shore where she was assessed as unconscious and apnoeic. A rescuer initially thought a weak radial pulse, described as a weak "*flutter*", could be felt. BLS was commenced, complicated by vomitus, water, bile and froth coming from the airway. After 10 minutes, another diver arrived with an AED which when attached indicated that no shock be given. At this time the victim had fixed, dilated pupils. Paramedics arrived soon after and commenced ALS. A 'shockable' cardiac rhythm was briefly created although subsequent defibrillation failed to restore sinus rhythm. There was continued difficulty ventilating the victim as the airway appeared to be obstructed by fluid and a "*gurgling sound*" was heard.

An equipment check on the beach showed remaining air as 90 bar. When the equipment was tested later it functioned correctly. Although the primary air supply hose was noted to be kinked at the first stage regulator, and seemed to have been so for some time, causing the air flow to the primary regulator to be restricted, there was no breathing problem encountered during a test dive by the police later so this was not thought to have been an adverse factor in this fatality.

Autopsy: Before commencing the autopsy (two days after death) X-rays of the head, neck, and trunk showed gas within the chambers of the heart and major vessels, including the cerebral arteries. The appearances were those of arterial gas embolism. The heart weighed 360 g and was normal with up to 20% narrowing of the coronary arteries. There was fine patchy replacement fibrosis in the heart on histology, which is not explained. The right and left lungs weighed 915 g and 740 g respectively and were well-expanded. There were gastric contents in the upper airways. The cause of death was given as CAGE.

Comments: The victim had passed a dive medical but had omitted to mention that she was taking dexamphetamine (25–30 mg daily) for adult-onset attention deficit hyperactivity disorder and also suffered from migraine. While her husband stated that she was taking medication daily for the former, no trace was found at autopsy. She was not taking any medication for migraine. The date of the X-ray examination is not recorded but probably preceded the autopsy. Given the two-day delay and brief description of the gas, the gas could

Table 2
Summary of scuba and surface-supply diving-related
BNS – buddy not separated; BSB – buddy separated before problem; BSD – buddy separated during problem; GSB – group separated before problem; n/a – not applicable; n/i – not inflated; n/s – not stated; BCD – buoyancy compensator;

ID	Age	Gender	Height (m)	Weight (kg)	BMI (kg m^{-2})	Training	Experience	Dive group
Scuba								
SC 07/01	45	F	176	84	27.1	just trained	none beyond training	GNS
SC 07/02	57	M	172	84	28.4	trained	experienced	GNS
SC 07/03	45	M	170	68	23.5	trained	some	GSB
SC 07/04	29	M	190	90	24.9	just trained	none beyond training	GSB
SC 07/05	62	F	165	75	27.5	nil	nil	BSD
SC 07/06	24	F	n/s	n/s	n/s	trained	some	BSB
SC 07/07	60	M	184	88	26.0	trained	some	BSB
SC 07/08	62	M	180	90	27.6	just trained	none beyond training	BNS
Rebreather								
RB 07/01	42	M	n/s	n/s	n/s	trained	experienced	BNS
Surface supply								
SS 07/01	38	M	181	101	30.7	trained	some	BSB

be the result of CAGE, decomposition, post-mortem off-gassing, or resuscitation. A number of features are consistent with CAGE, including the relative inexperience and loss of consciousness after surfacing. However, the description of her apparent distress underwater and breathlessness while ascending does not fit with typical CAGE. Given the evidence of pulmonary oedema at autopsy one might consider a diagnosis of scuba divers' pulmonary oedema (SDPE).[3] However, it is not possible for a pathologist to make this diagnosis in the absence of a history of previous episodes of shortness of breath while diving.

The victim reported being low or out of air at depth despite her contents gauge indicating more than half her air remaining. Examination of her equipment subsequently showed that the hose to her primary regulator was kinked (long standing) and that this kink restricted the airflow; however, a subsequent test dive with the equipment failed to show this to be a problem. Whether her feeling of being 'out of air' was down to this must remain a matter of conjecture. However, it is interesting to speculate that such a restriction to flow may have been a trigger to developing SDPE.

Summary: History of adult-onset attention deficit disorder; newly trained, inexperienced diver doing 26 msw dive on an advanced diver course; difficulty breathing at depth; controlled, assisted ascent with instructor; vomited and unconscious on surfacing; rescue breaths while towed to shore; CAGE?/SDPE?

SC 07/02

This 57-year-old male was an experienced diver who had qualified four years earlier and reportedly dived on most weekends. He had once been an alcoholic, but had abstained for 20 years. He had had a thyroidectomy, a high resection for Duke's 'B' bowel cancer and a left shoulder operation, and had a history of petit mal epilepsy, bipolar disease, and chronic obstructive airways disease (COAD). Medications included sodium valproate, dextropropoxyphene, vardenafil, naproxen slow release, tiotropium inhaler, oxycodone hydrochloride, paracetamol, olanzapine, lithium carbonate, and salbutamol. However, it was suggested that none of these conditions appeared to be causing him any problems at the time and it was not known which, if any, of the prescribed medications he was actually taking. It was reported that he was so keen to scuba dive that he sent a substitute to have a 'diving medical' in his name. He was also overweight and had reported to his doctor that he felt anxious when it came time to ascend at the end of a dive.

On the day before the incident, a witness who knew him reported seeing him break the surface rapidly after a dive and then lie motionless until the boat picked him up.

Table 2 (cont)
fatalities in Australian waters in 2007
+ sufficient air (to surface safely); ++ 1/4–1/2 full tank; +++ >50% full; nad – nothing abnormal discovered;
CAGE – cerebral arterial gas embolism; PBT – pulmonary barotrauma; SD – sub-dural; SDPE – scuba divers' pulmonary oedema

Dive purpose	Depth (msw)	Incident (msw)	Weight belt	Wts (kg)	BCD	Remaining air	Equip test	Disabling injury
training	26	bottom	off	8	inflated	++	nad	CAGE?/SDPE?
recreation	22	10	n/s	n/s	n/i	+++	nad	PBT/CAGE
recreation	6	surface	n/s	n/s	inflated	+	nad	asphyxia? cardiac?
recreation	19	surface	on	n/s	n/s	+	nad	CAGE
training	11	1.5	nil	0	nil	+	nad	asphyxia
recreation	12	n/s	on	n/s	n/i	n/s	n/s	asphyxia? SD haematoma?
recreation	25	surface	on	14	inflated	++	nad	PBT/CAGE
training	21	surface	on	n/s	inflated	+++	n/a	cardiac?
recreation	125	100	n/s	n/s	inflated	+++	n/a	asphyxia?
crayfishing	4	4	on	21	nil	+++	nad	PBT/CAGE

Apparently, the victim cancelled his next planned dive that day. Although a person who shared a room with the victim that night reported that he was "*in good spirits*", he was reported to have looked very "*unwell*" the next morning prior to the fatal dive.

This dive was a transit of a passage cave, starting at its deeper entrance at 22 msw and exiting at its shallower end at 10 msw, a distance of 125 metres. The victim had reportedly dived this cave about 12 times over four years. His buddy on this occasion was a very experienced diver who had also dived the cave before. They had no problems until they were nearing the exit where the victim rested on a rock, holding his chest and patting it. The buddy gave him an 'OK' signal several times and there was a delay before he responded. He took the victim by the arm and towed him to complete their exit into open water, at which point he rested again before ascending. When they reached about 10 msw, they both grabbed the dive boat's mooring rope. The victim then spat out his regulator, which the buddy replaced with his own secondary regulator before prising the victim's fingers off the rope and assisting him to the surface. During this ascent the victim became unconscious. On reaching the surface, the victim was pulled into another operator's dive boat and was found to be unconscious and apnoeic, and "*looked very grey*". BLS was commenced and continued after he was transferred to his original dive boat and taken to shore. There was no oxygen available on the boat during this 20-minute period. Paramedics were waiting at the jetty but there is no record of whether or not any ALS was implemented.

Examination of the equipment by the police showed 115 bar of enriched air nitrox (EAN) 31.5 remained in the cylinder. No faults were found in either the equipment or the quality of the gas. The victim's computer recorded that the ascent rate was greater than 18 msw min^{-1}.

Autopsy: The autopsy was carried out three days after death. X-rays were taken before autopsy but it is unclear how soon after death. These showed subcutaneous emphysema of the neck, chest and abdomen, a pneumoperitoneum and large gas bubbles within the great vessels of the chest and abdomen. There were rib fractures consistent with vigorous external cardiac massage. Autopsy revealed extensive subcutaneous emphysema, gas bubbles in the arteries at the base of the brain and in the lungs, and gas in the subepicardial veins and in the peritoneum. The right and left lungs weighed 675 g and 610 g respectively, and were distended and voluminous with subpleural blebs and some emphysema with apical adhesions. Histology showed multiple intra-alveolar and parenchymal haemorrhages and the blood vessels, including those of the alveoli, contained a significant number of spaces consistent with gas bubbles. The heart weighed 400 g and was normal with no coronary atheroma. The cause of death was given as decompression sickness.

Comments: The cause of death was given as "*decompression sickness*" but this is a highly unlikely diagnosis given the relatively mild exposure. With three days between death and autopsy, the gas seen could have been from post-mortem off-gassing, decomposition or resuscitation, rather than decompression sickness. There appears to be an event on the bottom before ascent where the victim rested on a rock, holding his chest. Whether he was feeling breathless or experienced anginal discomfort cannot be known. He may have sustained a CAGE during the ascent, especially given the presence of emphysematous blebs. Alternatively, it is possible that the rapid ascent on the day before could have caused pulmonary barotrauma (PBT) that precipitated the problem on this apparently uneventful dive. The description given by the buddy of events late in the dive indicates the victim lacked an alert response to his situation so could well have not been breathing correctly during the ascent, certainly so after he let his regulator fall out of his mouth.

The connection between epilepsy, cardiac arrhythmias and sudden death remains unclear but could be one explanation for the event on the bottom. His multiple medical problems including his COAD meant that this man was unfit to dive. That he was concerned about his ascents, and that he sent another person to undertake his diving medical, indicates that this diver was aware that diving with his medical conditions could have consequences and that they should have precluded him from diving.

Summary: History of emphysema, petit mal epilepsy, bipolar disorder, bowel cancer; experienced diver; familiar dive site; rested at cave passage exit with possible chest discomfort and/or breathlessness; unconscious during ascent; pulmonary barotrauma and CAGE

SC 07/03

This 45-year-old, apparently healthy male had completed approximately 15 dives prior to becoming certified, before which he had been medically assessed and been declared fit to dive. He then completed a further four dives over the following six months. He and three friends entered the ocean from a rocky shoreline. The victim's buddy was an experienced diver and they had dived together several times before. The water's surface was calm, but there was a powerful swell of up to one metre and the visibility was poor, often less than one metre. The depth of the site varied from 3 to 6 msw. They had agreed that each diver would surface once their air reached 80 bar.

Shortly after entering the water and submerging, the victim surfaced and requested more weights from his son, who remained on the rocks as an observer. After adding 2 kg to his integrated weights system, he re-submerged. The victim and his buddy had only sporadic contact owing to the poor visibility. The surge was strong and, at one time, the buddy saw the victim thrown upside down and into a rock by the surge, after which he lost contact with the victim and surfaced shortly afterwards when he reached the agreed air cylinder ascent pressure. The remaining divers returned to shore and, together with the victim's son, scanned the water for the victim. After about 20 minutes, a bystander reported seeing the victim floating some 300 metres from shore some 400 metres along the coast. She also reported that she thought she had seen him thrown into a rock by a wave. The son and one of the other divers swam to the victim who was found to be unresponsive and apnoeic. His BCD was partly inflated, his weights had been dropped and his mask, snorkel, one bootee and fin were missing. Rescue breathing was attempted as he was towed to shore, where ALS was provided by waiting paramedics without success.

When checked, the victim's pressure gauge read 40 bar and his dive computer indicated an underwater time of 23 minutes. When his equipment was tested later by police, no faults were found.

Autopsy: At the time of admission to the mortuary there was a film of frothy fluid around the mouth. A CT scan prior to autopsy showed no air embolism or pneumothorax. The pathologist described a 10 x 8 cm abrasion on the forehead, a 2-cm laceration on right hairline, left periorbital bruising, bruising and abrasion of his chin but no intracranial pathology. The right and left lungs, weighing 785 g and 660 g respectively, were over-expanded and showed 'emphysema aquosum', denoting drowning. The heart weighed 325 g and there was a 40–50% narrowing of the LAD macroscopically. Histology indicated a 70% narrowing of the LAD, but no ischaemic damage to the myocardium. The cause of death was given as drowning. The pathologist commented that it was possible that the diver suffered an arrhythmia while diving.

Comments: It was apparent from witness reports and the head injury that the diver was thrown against rocks at some point but it is unclear if this occurred before or after he became unconscious. In either case, such trauma could have resulted in subsequent drowning. The condition of his LAD coronary artery raises the possibility of a cardiac factor, as suggested by the pathologist. These challenging sea conditions were likely to have been beyond the capabilities of this relatively inexperienced diver with significant, although possibly unknown, cardiovascular disease.

Summary: Apparently healthy; trained; limited experience; poor visibility; buddy separation; strong surge; head trauma; inflated BCD and ditched weights; severe atheroschlerosis; drowning (with possible cardiac involvement)

SC 07/04

This 29-year-old male was a foreign national working in Australia. His workmates described him as fit and athletic and he ran regularly. However, it was also reported that

he had been suffering on and off from a cold/flu over the previous two months and a variety of medications were later found in his hotel room causing the coroner to state that the victim had "*suffered from a number of respiratory tract infections of uncertain severity*". He had completed dive certification two weeks earlier for which he had successfully undergone a dive medical examination by a doctor with relevant training. He completed four dives as part of training and one post-certification dive.

On the day of the fatal dive, the victim and three other certified divers went diving under the supervision of an instructor. The conditions were described as perfect, being sunny with a light wind, calm sea and minimal current. The dive, to a maximum depth of 19 msw, appeared to be problem-free and, when the victim indicated that his gauge read 60 bar, the instructor escorted him to the safety stop before re-descending to join the others, still keeping the victim in sight. The dive time to this point was 32 minutes. After a safety stop of three minutes at 5 msw, the victim was seen to ascend, apparently normally. On reaching the surface, he gave an 'OK' signal to an observer on the boat, then changed to his snorkel and snorkelled to the boat. However, when trying to climb the ladder he collapsed back into the water. When the victim was brought aboard the boat he was unconscious although initially he appeared to be breathing spontaneously and so was placed in the recovery position. However, soon afterwards he was found to be apnoeic and BLS was commenced, with rescue breathing enhanced by supplemental O_2. A rescue helicopter brought paramedics who attempted ALS before confirming his death.

When his equipment was later examined by police, no likely adverse factors were found. His dive computer indicated that he had exceeded the recommended ascent rate of 10 msw min^{-1} although the actual rate was not shown. The remaining air pressure in the cylinder was 20 bar.

Autopsy: The autopsy was informed by a knowledge of underwater medicine, a CT examination of the head and chest being performed before commencing the autopsy, and the neck vessels being clamped before the skull was opened. The small vessels over the brain contained small gas bubbles but these were ascribed to decomposition changes. However, brain histology revealed numerous petechial haemorrhages throughout the white matter of both cerebral cortices, pons and mid brain, consistent with air embolism. Gas was present in the basal artery and Circle of Willis. The right and left lungs were very heavy, weighing 1,240 g and 1,160 g respectively, and both lungs showed numerous air bullae up to 15 mm in diameter over their surfaces. Cavitation was seen within the lungs, maximal on the left side, and both lungs showed gross oedema and congestion.

The pulmonary trunk, aorta, inferior and superior vena cavae and pulmonary veins were clamped or ligated before removing the heart, which was opened under water. Bubbles of gas escaped from the right atrium and ventricle and to a lesser extent from the left atrium but not from the left ventricle. Visible gas was present in the anterior descending and circumflex branches of the left coronary artery. No atheroma was present. The heart weighed 450 g and showed a moderate degree of concentric thickening but no evidence of any myocardial fibrosis or infarction, or of hypertrophic cardiomyopathy. Examination of the victim's medications suggests that he had respiratory symptoms. The cause of death was given as air embolism (CAGE).

Comments: According to witness reports, this diver appeared to have conducted a well-controlled and problem-free dive. While the dive computer indicated his ascent rate had exceeded 10 msw per minute, no witness reported that his ascent rate appeared to have been excessive. It is possible that the victim's previous respiratory conditions could have contributed to his death through air-trapping during ascent. It is also possible that this inexperienced diver was not exhaling adequately during ascent. However, this is speculation.

Summary: Apparently fit; respiratory infections over previous months; certified two weeks prior; recent dive medical; second post-certification dive; good conditions; dive appeared problem-free; collapsed shortly after ascent; CAGE

SC 07/05

This 62-year-old female was described as healthy and physically fit and was keen to learn to scuba dive so that she could do so with her new partner, who was a diver. Although not a qualified instructor, her partner had begun to teach the victim some basic skills in a neighbour's pool. On this occasion, the two planned to practise skills in the shallows of a river. The victim was wearing a bathing costume and mask, as well as a scuba tank with harness and regulator. Neither she, nor her partner wore a BCD or fins. They entered the water and waded to a depth that was neck-deep for the victim and intended to kneel on the bottom and practise skills. The visibility was about 0.4 m and the victim's cylinder was one quarter full. The water temperature was approximately 26°C.

Unfortunately, they were unaware that recent floods had scoured an 11-metre-deep channel near the sandy bank and the victim inadvertently stepped into this channel. The partner heard her call "*Help!*" before she began to sink. Although she was a strong swimmer, without fins or a BCD she could not ascend. The partner realised the problem and tried to unbuckle the harness, but only managed to release the strap securing the tank, believing that this would cause the tank to fall away and so enable the victim to swim to the surface. He was unable to release the other straps partly because she had accidentally knocked off his mask in the ensuing panic. He then tried to support her and assist her to the surface but was unable to do so. He could no longer see the victim because of the low visibility so he exited the water to seek help, which was not readily available.

Police divers found the victim's body the next day. The 11.6 litre steel scuba tank was found first, with the belt undone. The contents gauge showed less than 50 bar remaining air. The equipment was later examined and found to function correctly. A test dive showed that a person without fins would be unable to swim back to the surface using arms and legs from 11 metres' depth, and that the weight of the tank made it difficult to maintain an upright position in the absence of fins and other buoyancy and pulled the wearer down backwards when not trying to swim to the surface. The police concluded that there were no suspicious circumstances surrounding this death.

Autopsy: The heart weighed 314 g and showed only mild coronary atheroma with a healthy myocardium. The right and left lungs weighed 622 g and 594 g respectively and were well-inflated. There was no pulmonary oedema fluid in the upper airways and only mild to moderate pulmonary oedema on the cut surface. The cause of death was given as drowning.

Comments: Although this stretch of the river was well known to the victim and her partner (being on his property) they were tragically unaware that what was previously shallow water, where it might have been relatively safe to practice certain skills, had recently changed. However, it is seldom appropriate not to wear fins with scuba. The wearing of a BCD and ability to inflate it might have averted this accident. It is likely that the victim removed her regulator when calling for help and failed to replace it effectively, causing her to aspirate water and lose consciousness as she sank to the bottom. Autopsy findings in fresh-water drowning are more subtle than those of salt-water drowning and with early decompositional changes (two days between death and autopsy) pulmonary oedema fluid in the upper airways may be absent.

Summary: Apparently fit and healthy; minimal scuba training by non-instructor; not wearing fins or BCD as planned to be in shallow water only; inadvertently stepped into deeper water and sank; poor visibility; buddy unable to rescue; drowning

SC 07/06

This diver was a 24-year-old, female, overseas tourist who was visiting an island off the south-west coast of Australia with her boyfriend. She had been certified six months earlier and this was her eighth dive. The couple were diving from a commercial dive boat with other certified divers. The conditions were described as calm, with a swell of less than 2 m, a light wind and visibility of up to 5 m. After the briefing, the victim and her boyfriend asked the divemaster/instructor if he would accompany them on this dive due to their inexperience. He agreed and they set off together. After descending, the divemaster initially helped the victim adjust her buoyancy and held her hand as they swam. After a few minutes, she signalled that she was 'OK' so the instructor swam ahead of the victim and her buddy, looking back to check on them periodically. At one point, the divemaster looked back and could not see the pair so swam back to look for them. He soon found the buddy but the victim was not with him. The buddy indicated that the victim was 'OK' but had returned to the surface and signalled for the divemaster to continue the dive with him. However, after about a further five minutes, the divemaster found the victim floating near to the bottom, unconscious and with her regulator out of her mouth. He quickly ditched her weight belt, brought her to the surface and towed her to the nearby boat, providing two rescue breaths on the way.

The victim was soon dragged onto the boat and assessed as unconscious, apnoeic and pulseless. BLS was commenced but was complicated by large amounts of water and white frothy sputum in the airway. In response to a distress call, a doctor on a nearby boat and two nurses from the island arrived and implemented ALS after which a pulse was palpable and the victim began to breathe spontaneously. She was transferred by boat to the island and then evacuated by aircraft to the nearest hospital for initial assessment and stabilisation, and from there to a tertiary hospital where neurological services were available. Investigations at the initial hospital revealed a small right subdural haematoma and marked right mass effect throughout the right cerebral hemisphere. No fractures or right scalp haematoma were observed. Neurosurgical opinion was that the subdural haematoma was too small to warrant evacuation and EEG data were consistent with a severe hypoxic brain injury. She remained in a coma and was eventually repatriated to her home country, still on a ventilator, where she remained hospitalised without improvement. It is reported she eventually died there as a result of severe hypoxic injuries.

The dive master's dive computer indicated that the maximum depth of the dive was 12 msw with a dive time of 15 minutes.

Comments: This diver eventually died in her home country and the death should have been referred to the coroner there. Coronial investigations become much more complicated and often unsatisfactory when the event occurs in one jurisdiction and the death occurs in another jurisdiction. There was evidence of aspiration of salt water and a right-sided subdural haematoma. The haematoma could have been the result of blunt trauma occurring prior to the dive (with a latent period), during water entry, or during the dive, or maybe contact with the boat hull in the swell when surfacing near the boat. It is also possible that the subdural haematoma occurred during diver recovery and was not directly relevant to the death.

Less commonly a subdural haematoma may occur with subarachnoid haemorrhage associated with a berry aneurysm, or AV malformation (not seen on angiogram), coagulopathy (normal coagulation studies make this unlikely), or malignancy or associated with cerebral atrophy. Spontaneous non-traumatic subdural haemorrhage is rare but described. The CT scan was performed without contrast,

which probably limits its diagnostic accuracy. The absence of a skull fracture probably says little about the mechanism of the subdural haematoma, and subcutaneous bruising from blunt trauma could have been concealed by the scalp hair.

The possible causes of death are hypoxic brain damage due to drowning following head injury, or hypoxic brain damage due to drowning. This case demonstrates that an autopsy is a useful part of a gold standard investigation of a diving death. It is unfortunate that the buddy did not accompany the victim to the surface as this might have saved valuable underwater recovery time.

Summary: Apparently healthy; inexperienced diver; accompanied by buddy and divemaster; separation; found unconscious near to the bottom; small subdural haematoma on CT scan; ALS successful; remained comatose; repatriated; reported to have died

SC 07/07

This victim was a 60-year-old male who was described as healthy and very fit. He had learned to dive in the Philippines approximately two years earlier and had reportedly done 16 dives, almost all in the Philippines prior to enrolling to dive with a dive club in southern Australia. He had purchased his own second-hand diving equipment which had reportedly been serviced prior to sale. Two days prior to the day of the fatal dive he conducted two 10–15 msw drift dives in an area prone to currents. His buddy was a very experienced diver who guided him on these dives to familiarise him with use of the drift line. The victim was described as looking uncomfortable and was having trouble maintaining correct buoyancy and horizontal orientation. He was wearing dentures and, on the second dive, bit too hard on these, causing them to fracture. This was possibly an indication of his level of anxiety.

On the day of the accident, the victim, now wearing an old set of dentures, dived with the same buddy from the dive club boat, driven by another club member. On the first dive, a drift dive to around 20 msw, the victim continued to struggle with buoyancy control and orientation and used his air supply quite quickly. After a surface interval of approximately four hours, the divers prepared to dive again. The conditions were described as calm, with visibility of around 4–5 metres. The current was variously reported to be between 1 and 3 knots. The divers were using a 100-metre buoyed drift line fitted with two 10-metre lengths at the bottom. The victim was instructed to hold onto the end of one of these. The depth ranged from 16–25 msw.

During the first 10–12 minutes, the buddy occasionally sighted the victim but then did not see him for the remainder of the dive. Approximately 15 minutes after the divers descended, the boat driver saw the victim surface 300 metres away. He was face-up with a partially inflated BCD and was not moving. The boat driver was unable to bring him aboard and so radioed for assistance. Others arrived and brought the victim on board. He was unconscious and apnoeic and there was froth in his mask. It appears that BLS was not commenced for approximately 15 minutes. Eventually, a policeman and an off-duty paramedic arrived and took over resuscitation efforts. A bag-valve-mask with supplemental O_2 was used for some of the time. After approximately 30 minutes of BLS without response the paramedic declared the victim to be deceased. He was not wearing any dentures and none were later found.

His equipment was found to be functional and no significant defects were indicated. There was 70 bar of air remaining in his cylinder.

Autopsy: A CT examination was made before commencing the autopsy and was reported by an experienced forensic radiologist. This showed there was widespread intravascular gas collection predominantly in the left side of the heart and arterial structures highly suggestive of pulmonary barotrauma/CAGE and not typical for decomposition or post-mortem off-gassing (post-mortem decompression). At the autopsy, the pericardial sac was opened and filled with water, then each ventricle was pierced in turn. About 15–20 ml of gas escaped from the left ventricle, and a small amount of gas was released from the right ventricle. The heart weighed 366 g and appeared to be healthy. The coronary arteries showed no significant stenoses. There was a copious escape of blood and gas when the carotid artery was opened. There was little if any gas noted outside the vascular system. Gas was noted in the hepatic and portal veins. Before removing the brain, the internal carotids and basilar arteries were ligated. Copious amounts of gas were noted within the entrapped Circle of Willis, and copious amounts escaped from all arterial outlets when cut.

The lungs were hyper-inflated and entirely covered the anterior heart contour. The right and left lungs weighed 820 g and 685 g respectively. There was a small amount of lightly blood-stained pulmonary oedema fluid in the trachea. All the lobes elicited considerable crepitus on compression. Histology of the lungs showed evidence of widespread alveolar rupture and also a subpleural gas collection was identified. In some areas, the pleura was separated from adjacent parenchyma. No pre-existing, significant, naturally-occurring disease was noted. The brain showed mild congestion and oedema. Numerous intraparenchymal blood vessels showed gas dissection of the wall and separation of the wall from adjacent parenchyma. There was a firm diagnosis of pulmonary barotrauma and CAGE.

Comments: This diver had relatively little experience in cooler waters and strong currents. The drift line being used enabled the divers to be up to 20 m apart. This was not appropriate with a relatively inexperienced diver in low visibility and what could have been a strong current. Evidence from a dental expert advised that it was likely that an old pair of dentures would be ill-fitting and probably

loose, making it reasonably easy for them to fall out while diving. If so, it is probable that a diver would be unable to grip his regulator effectively. The victim might have had difficulty with his dentures, aspirated some water, inflated his BCD and surfaced with inadequate exhalation. This is a well-documented example of pulmonary barotrauma and CAGE.

Summary: Few dives since trained in tropics; little experience in drift diving; using old and likely ill-fitting dentures; poor buddy contact leading to separation; possible aspiration; panic and uncontrolled buoyant ascent; CAGE

SC 07/08

This 62-year-old male was described as a heavy drinker with a recent history of hypertension and hyperlipidaemia. He had completed his open-water diver training the day before and had very recently been assessed as fit to dive. On this occasion, he and another diver were to dive with an instructor, leaving two other staff on the boat. Surface conditions were described as choppy but not rough, but during the snorkel to the anchor line the other diver aborted the dive. The instructor asked the victim if he was ready to continue to which the victim replied that he needed a minute to catch his breath. When he felt ready, the victim signalled to the instructor to descend. He then signalled 'OK' to the instructor at approximately 13 msw as they passed through a thermocline (of 12^{O}C). On the bottom, at about 20 msw, the victim wrote "*breathing fast*" on the instructor's slate but after relaxing for a minute he signalled that he was 'OK' to proceed. During the tour portion of the dive, the victim appeared to be relaxed, in control and having a good time.

After a circuit of the site, the pair returned to the anchor and the instructor, noting that they had plenty of air remaining, signalled to the victim asking if he wanted to continue the dive. The victim almost illegibly wrote "*tired*" on the slate and then signalled to ascend. At the 5-msw safety stop the victim returned an 'OK' signal and showed no signs of distress, his breathing and body positioning appearing to be normal. However, after only about one minute, the victim started to ascend and did not respond to the instructor's signals to return to the safety stop. The instructor surfaced to find the victim unconscious face-down in the water. His eyes were glassy and open and, although the regulator was still in his mouth, he did not appear to be breathing.

The instructor and another person who had been on the boat as deckhand responded quickly and gave some rescue breaths while ditching the victim's equipment. Once on the boat, BLS was commenced and after a couple of minutes one of the rescuers noticed what appeared to be a fluttering in the victim's neck and thought that he could feel a pulse. He also noticed that the victim appeared to take an unaided breath so he was placed in the recovery position and given supplemental oxygen. However, it was soon apparent that he was apnoeic and BLS was re-commenced and continued until reaching shore where waiting paramedics initiated ALS, without success.

Most of the victim's equipment was lost after being ditched but his cylinder was examined and found to be serviceable. There was no mention in the police report as to whether the regulator was still on the cylinder.

Autopsy: The coroner recorded the cause of death as undetermined as there was no convincing anatomical cause of death. Post-mortem X-rays showed no accumulation of gas in the chest. There was no evidence of pneumothorax or embolism. The heart weight was at the upper range of normal (442 g) and there was moderate diffuse atheroma of the coronary arteries with up to 50% narrowing of the LAD macroscopically. There was no evidence of recent or old myocardial infarction. The right and left lungs weighed 942 g and 818 g respectively, and were well-expanded. No pulmonary oedema was described in the upper airways. Toxicology detected pseudoephedrine. The pathologist gave the cause of death as undetermined.

Comments: There was a history of hypercholesterolaemia, hypertension and heavy alcohol use. While no clear cause of death was found at autopsy, the history, the borderline cardiac weight and the moderate coronary atheroma all suggest a cardiac arrhythmia (an event that cannot be demonstrated at autopsy). As was shown in case BH 07/08, histological examination of the coronary arteries may demonstrate a greater degree of stenosis and the presence of an unstable plaque that might not be appreciated on macroscopic examination. Histology of such lesions is probably desirable. A combination of exertion, cold, pseudoephedrine and other possible dive-related factors likely caused this diver to suffer from a cardiac arrhythmia which rendered him unconscious. What was thought to be a return of spontaneous respiration was probably agonal breathing.

Summary: History of heavy drinking, hypertension, hyperlipidaemia; recently passed dive medical; first dive immediately after training; breathless and tired during dive; unconscious on surface; possible arrhythmia?

Rebreather fatality

RB 07/01

This victim was a 42-year-old male who was reportedly fit and healthy, although a heavy smoker. He was an experienced technical and wreck diver and part of a group dedicated to finding and diving deep wrecks. He was experienced in the use of his Inspiration Classic closed-circuit rebreather (CCR). As well as his rebreather, he was carrying two 12-L bail-out cylinders for emergency open-circuit use in the event of a rebreather failure. The gas composition in these cylinders was unknown. On this occasion, the victim was among a group of eight divers whose objective was to make a positive identification of a wreck thought to be an ore

carrier torpedoed during World War II, lying at a depth of 125 msw. All those present had made careful calculations of their dive profiles, a multi-hour decompression schedule and extensive 'bail-out' open-circuit planning.

The divers entered the water and descended to 5 msw depth where they made a final check of each other's equipment. They then descended together down the shotline. At around 70 msw, the buddy heard the audio alarm of an Inspiration. He checked his own equipment and found nothing wrong, but was unsure if the victim checked his. At approximately 90 msw on the shotline, the victim stopped and signalled that he needed assistance to connect a hose from his bail-out cylinder to his manual diluent connection. The buddy assisted with this and, after it had been connected, the victim signalled with a 'thumbs up' which was taken to mean that all was 'OK'. The descent was resumed but with the alarms still sounding. At approximately 100 msw, the victim stopped on the shotline and he failed to respond when his buddy tapped on his rebreather. When the buddy swam in front of the victim he noticed that the dive surface valve (mouthpiece, DSV) of the rebreather was out of his mouth, his eyes were shut and one hand was holding the shotline. The buddy tried in vain to replace the victim's DSV and inflate his drysuit but was unable to do so in the strong mid-water current.

At this point another diver, who had noticed there was a problem, came to assist. He also attempted to inflate both the victim's drysuit and BCD without apparent success. The three continued to descend and reached the bottom of the shotline. The second diver released the victim's weight belt but he remained negatively buoyant. Both divers tried to hold onto the victim but lost their one-handed grip on him as the shotline was dragged by the current across the seabed. There was no current on the seabed itself and the victim's heavy body was left behind as they were swept onwards. The divers realised that they already had a decompression obligation of approximately 3.5 hours so made a decision to begin their long and slow ascent. When closer to the surface, one of the divers sent up a message by a marker buoy reporting what had happened and asking for the police to be informed. Decompression risk prohibited any search being made by the other divers, and the police divers are neither trained nor permitted to dive to this depth.

It was thought the victim's heavy body would remain where it was but a later police search using side scan sonar failed to locate it, though there was some doubt as to whether the correct dive location was identified by the dive boat's skipper. Although the divers had left the shotline buoyed at the dive location, it was not there when the police search was made. The victim's body has not been found.

Comments: Deep mixed-gas diving using rebreathers is a hazardous undertaking at the best of times. Conducting such dives off-shore and in a strong current adds substantially to these risks. In this case, the dive group had set up systems that they believed would minimise risk, including having a dive supervisor who remained on the surface and various check lists to ensure that all divers had suitable plans and had performed pre-dive checks. However, the utility of such systems is severely compromised where there is substantial variation and modification of equipment such that the supervisor is unable to ascertain or independently verify that the various divers are entering the water with their gear configured correctly.

The Inspiration Classic is a CCR rated for use to 100 msw using trimix (O_2/He/N_2) diluent. The unit has been tested to 150 msw using heliox diluent. It consists of a breathing loop with a set of one-way valves and a chemical carbon dioxide (CO_2) scrubber. Two 3-L (water volume) cylinders, one with O_2 and the other a diluent gas, supply breathing gas to the unit. Exhaled gas passes through the scrubber material where CO_2 is removed. O_2 sensors then detect the partial pressure of O_2 (PPO_2) in the residual gas and O_2 is added by an electronic solenoid controlled by computers to maintain a constant inhaled PPO_2 (usually 131 kPa, 1.3 ATA). As the diver descends, the loop would be crushed unless additional gas is added. This gas, known as the diluent gas, is usually either trimix or air depending on the planned depth. During ascent, gas must be vented from the unit. Because the diver must drive the gas around the unit through the action of breathing, issues such as gas density and work of breathing become critical at depths such as were planned in this case, and correct gas choice is vital.

With the Inspiration Classic, the standard set up is that the on-board diluent cylinder provides gas for the breathing loop, and BCD. However, in this case, it is believed that the victim had planned to use diluent from his off-board 'bail-out' cylinder for breathing and the on-board cylinder for drysuit and BCD inflation (and hence which contained air rather than trimix). Photographs taken just before the victim dived appeared to show that the 'bail-out' cylinder was not connected and that the automatic diluent addition valve (ADV) was still connected to his on-board cylinder (i.e., air).

The victim had done considerable research into this wreck and was keen to be the person to positively identify it. Thus, there was substantial pressure to do the dive, which may have added to stress and acted as a distracter. It would seem most likely that the victim entered the water and descended with the unit running with air as its diluent. At 70 msw, the PPO_2 of the breathing loop would reach 163 kPa (1.6 ATA) causing the alarms that were heard by the buddy. By 90 msw, the PPO_2 would have been 183 kPa (1.8 ATA) and at this depth the victim would almost certainly have been suffering from considerable nitrogen narcosis, perhaps explaining his inability to 'plug in' the off-board diluent hose.

The victim's buddy mentions that the victim then did some checks after the cylinder was plugged in and signalled to proceed. This statement seems inconsistent in that:

- the signal for 'OK' is not the 'thumbs up';

- correct procedure for checking the presence of an incorrect diluent would involve flushing and venting the breathing loop with a considerable quantity of gas, an event that one would have expected the buddy to comment on had it occurred;
- the descent was recommenced with the victim's alarms still sounding.

If the victim did not flush the breathing loop, then the majority of the gas present would have continued to have been air, leading to nitrogen narcosis and elevated CO_2 levels from a high work of breathing, both of which would seriously impair the victim's judgment. It is possible that the victim may have planned to 'breath down' the high PPO_2 if he was indeed aware of it. In this scenario, the high N_2 or CO_2 would have been enough to render the victim unconscious as would a high PPO_2 if the victim convulsed; the latter being a strong possibility given the probable circumstances. That the buddy did not stop the dive with the alarms sounding, or consider the implications of plugging in the off-board cylinder under these circumstances, seems very surprising given the level of diving being conducted. It is even more concerning that he allowed the descent to recommence at 90 msw with alarms still going. Once the victim was unconscious with the DSV out of his mouth, his chances of recovery from this depth were negligible. The inability of the rescuers to inflate the wing and dry suit is unsurprising. The diluent cylinder on the Inspiration rebreather has a 3-litre water volume. At 200 bar this equates to 600 litres of available gas. When the victim became unconscious and the DSV fell from his mouth, the CCR would have flooded, making the victim substantially negatively buoyant. The 16 kg lift BCD that is standard with this unit would take 210 litres of gas alone to inflate fully at this depth. If gas from this cylinder had been used for diluent as well as dry-suit inflation during the descent, this would have left insufficient gas to fully inflate the wing or dry suit at depth to counter the loss of buoyancy, especially if any gas had been used to purge the loop during rescue attempts.

Summary: Apparently healthy; trained and experienced technical diver; using closed-circuit rebreather; deep wreck at 125 msw; became unconscious at 100 msw; strong current and depth made body recovery hazardous; probable oxygen toxicity; probable drowning; body not recovered

Surface-supplied breathing apparatus

SS 07/01

This victim was a 38-year-old male who had been certified to dive six months earlier at which time, although obese, he had been assessed as fit to dive. He had done five or six dives since. He and a friend were diving for crayfish using a surface-supply system with two hoses. It is unknown if the victim had used this equipment before. He wore a wetsuit, mask and fins but no BCD or harness for the air hose. He also wore two weight belts, one with 17 kg and the other with 4 kg. The dive site was shallow at 3–4 msw but there was thick kelp in one area. The sea conditions were described as calm with a swell of less than two metres.

The divers had been in the water for around 30 minutes when the victim surfaced with his regulator out and signalled to be pulled to the boat by the hose, shouting "*Quick*". Pulling on his airline the friend in the boat determined that it was snagged in kelp and a line was thrown to the victim. He was pulled to within 6 m of the boat but was unable to be retrieved any further and, upon releasing the rope, sank from sight. The boat driver jumped into the water to try to support the victim but was unable to do so as he was too heavy. He then re-boarded the boat and tried to get the boat to the victim but the engine stalled. These actions brought the buddy to the surface and he was directed to where the victim was last seen. He found the victim tangled in kelp, unconscious and with the regulator out of his mouth.

On the surface, the victim was still entangled in both kelp and his airline and he needed to be cut free before the buddy and others could get him out of the water. When eventually he was brought aboard the boat, BLS was commenced and continued for over 45 minutes while the arrival of police and paramedics was awaited. On arrival, they took over resuscitation efforts, without success. When the victim's airline was cut, air spilled into the water showing that the compressor was still delivering air to that line. It was later determined that, although old, all the equipment was in working order and did not contribute to this death.

Autopsy: Unfortunately the pathologist was not notified of this death until many hours later and as a result, a CT scan was not performed. There was significant gas in the right ventricle and a lesser amount in the left ventricle and the aorta. There were also some small bubbles in the arteries at the base of the brain. The heart was heavy (496 g) with minimal atherosclerosis. There appeared to be some intimal/medial thickening of the small vessels surrounding the AV node. The pathologist noted that the significance of this was not clear although it had previously been described as a possible cause of cardiac arrhythmia during exercise.[4] The right and left lungs, weighing 1,258 g and 1,078 g respectively, were over-expanded and there was severe pulmonary oedema in the lungs and upper airways consistent with drowning. Two possible causes of death were given:

- PBT/CAGE followed by drowning due to loss of consciousness.
- Drowning due to loss of the regulator probably owing to snagging on kelp.

The pathologist favoured the former diagnosis.

Comments: This inexperienced diver was grossly over-weighted with two weight belts, and it was likely that it would have been difficult to release one or both of these in an emergency. He had no other options as he was not wearing a BCD. It is likely that he and/or his hose became entangled in kelp, his regulator dislodged and he made a panicked ascent with inadequate exhalation, resulting in

Table 3
Root cause analysis of diving-related fatalities in Australian waters in 2007
BCD – buoyancy compensator; CAGE – cerebral arterial gas embolism; CVD – cardiovascular disease; SD – subdural haemorrhage; PBT – pulmonary barotrauma; SDPE – scuba divers' pulmonary oedema

Case	Trigger	Disabling agent	Disabling injury	Cause of death
BH07/01	Tight jacket, alcohol?	Aspiration of water	Asphyxia	Drowning
BH07/02	Tangled in speargun cord	Entrapment	Asphyxia	Drowning
BH07/03	Water inhalation via snorkel?	Cardiovascular disease	Cardiac incident	Cardiac-related
BH07/04	Nausea? Alcohol?	Aspiration of vomit	Asphyxia? Cardiac incident?	Aspiration pneumonitis
BH07/05	Exertion	Cardiovascular disease	Cardiac incident	Cardiac-related
BH07/06	Unknown (poor swimmer)	Aspiration of water	Asphyxia	Drowning
BH07/07	Unknown (poor swimmer)	Entrapment? Mitral valve prolapse?	Asphyxia? Cardiac incident?	Drowning
BH07/08	Unknown	Cardiovascular disease?	Asphyxia? Cardiac incident?	Drowning
BH07/09	Exertion	Cardiovascular disease	Cardiac incident?	Drowning
SC07/01	Breathing difficulty? SDPE?	Ascent related? SDPE?	CAGE? SDPE?	CAGE. (SPDE?)
SC07/02	Medical condition?	Ascwent related	PBT/CAGE	CAGE
SC07/03	Rough conditions, exertion	CVD? Blow to head?	Asphyxia, cardiac incident?	Drowning
SC07/04	Unknown	Ascent-related. Medical condition?	CAGE	CAGE
SC07/05	Stepped into deep water	Buoyancy-related (no BCD)	Asphyxia	Drowning
SC07/06	Subdural haemorrhage	Medical condition (SD haem)	Asphyxia	Drowning (delayed)
SC07/07	Loose denture?	Aspiration of water	PBT/CAGE	CAGE
SC07/08	Exertion, cold? Pseudoephedrine?	Cardiac-related	Cardiac incident?	Cardiac-related?
RB07/01	Incorrect gas mix	Oxygen toxicity	Asphyxia	Drowning?
SS07/01	Entanglement/loss of air supply/over weighted	Ascent-related? Buoyancy-related?	Asphyxia? CAGE?	Drowning

pulmonary barotrauma and CAGE. Unable to stay on the surface, he sank and drowned.

Summary: Apparently healthy but overweight; inexperienced; using surface-supplied air; thick kelp; entangled in hose and kelp; loss of regulator; over-weighted and with no BCD; drowning (possibly partly owing to CAGE)

Discussion

As stated previously, the main purpose of these reports is to highlight problems so that similar events can be minimised in the future. As well as describing each event and drawing conclusions from the facts, including autopsy findings, we use a sequence of four events – trigger, disabling agent, disabling injury and cause of death – to provide a simple root cause analysis of each fatality (Table 3).

In this series, there were no cases of breath-hold divers who were believed to have died as a result of apnoeic hypoxia; we hope that this continues in future reports. At least two of the breath-hold divers were reported to have been poor swimmers, which is not uncommon, especially among visitors to the GBR. Life vests can provide valuable

additional buoyancy for snorkellers. However, these need to fit comfortably and provide effective buoyancy. Unfortunately, many life jackets and BCDs do not prevent an unconscious wearer from floating face-down and, in these circumstances, will not prevent a drowning.

Two of the compressed gas victims (SC 07/05 and SS 07/01) were not wearing BCDs and found themselves in situations where a BCD may have provided the required buoyancy to enable survival. All compressed gas divers should wear BCDs and fins in any situation where they may not be able to stand with their head clear of the water.

The incident BH 07/01 raises the concern of the challenges of providing a thorough briefing prior to diving-related activities, especially when different languages are involved. We strongly advise that intending snorkellers be competent swimmers and sufficiently fit and healthy. Snorkelling operators should pay careful attention to pre-screening participants for apparent health and fitness, anxiety, swimming ability and snorkelling experience to identify those who will need better orientation to the use of snorkelling equipment (especially effective clearing of water from the mask and snorkel), and closer supervision. Careful attention should also be paid to ensuring that the equipment is functional and a good fit.

Data from DAN America have identified cardiovascular disease as a possible contributing factor in 26% of scuba diving-related fatalities.[5] In this 2007 Australian case series, cardiac-related factors were thought likely to have been the disabling injury in three of the snorkelling deaths (BH 07/03, BH07/05 and BH 07/09) and may have contributed to another five deaths (BH 07/04, BH 07/07, BH 07/08, SC 07/03 and SC 07/08). There is currently debate about the necessity of a fitness-to-dive assessment by a doctor prior to open-water certification.[6,7] Although such a medical is still required under the current Australian Standards for recreational scuba diving (AS 4005.1), the major recreational training agencies operating in Australia no longer encourage this and many dive operators have consequently abandoned the practice in order to minimise barriers to course enrolments. However, with an ageing diving population, there is an increased potential for known or occult disease, and DAN America data indicate that increased age is associated with a higher dive-related mortality from cardiac as well as other causes.[5] It will be interesting to observe over time whether or not the abandonment of the mandatory medical in Australia is associated with an increase in morbidity and mortality, although this may be difficult to determine epidemiologically.

Fitness-to-dive assessments are fallible and have some inherent limitations as relatively few tests are usually performed. The assessment also relies on the candidate to be thorough and honest about their medical history. Although most divers who undergo diving medicals are assessed to be low risk, a dive medical, especially one performed by a doctor with appropriate training, will sometimes determine that an individual has an unacceptable risk of an accident while diving.

In this case series, although several divers had recently been assessed as fit to dive, pre-existing health conditions may have contributed to their deaths. The victim in SC 07/02 with a history of emphysema and petit mal epilepsy, among other conditions, would have undoubtedly been counselled not to dive by most dive physicians. However, it appears that he gained the required medical by using a substitute for the examination. The victim in SC 07/04, with a recent history of recurrent chest infections, was determined to be fit to dive, and this raises questions on the level of investigation required when such a history is provided. The victim in SC 07/01 failed to declare that she was suffering from attention deficit disorder, possibly through fear that she would be advised not to dive. However, had she declared her condition, she would likely have been assessed as fit to dive by many diving physicians. We believe cardiac arrhythmias could have been the disabling injury with SC 07/03 and SC 07/08, both of whom had recently undergone medical assessments.

It is worth noting that the (lay) rescuers in SC 07/08 ceased BLS after several minutes in the belief that a spontaneous pulse and respirations had returned. There is evidence that pulse checks are often performed poorly by laypersons, and even by some medical professionals, with false positives and false negatives common.[8–11] There are also data that suggest lay rescuers have difficulty in accurately assessing breathing and are often unable to recognise agonal gasps, which are common after cardiac arrest and which do not provide effective ventilation.[12–14] For this reason, lay rescuers are now advised to begin BLS if the victim is unresponsive and not breathing 'normally' (i.e., breathing regularly and not gasping), and to continue until responsiveness or normal breathing returns, unless it is impossible to continue (e.g., exhaustion), and until health-care professionals arrive and direct that BLS be ceased.[15] The rescuers in BH 07/09 abandoned BLS after only five minutes, seemingly without any of the suggested cessation triggers. AEDs were available in four of these events although, by the time they were attached, no shock was advised in three of these cases, probably because of the delays associated with the rescues. In one case where there was a very rapid response, several shocks were advised but the victim failed to recover.

Six of the ten compressed gas divers were inexperienced, having completed ten or fewer dives. Indeed, three had completed their open-water training within the previous 1–14 days. Inexperience and medical factors appeared to have contributed to the demise of these new divers.

Case RB 07/01 reflects the fact that divers conducting high-risk diving activities must have clearly defined criteria for aborting the dive if things are not going well. In this particular case, there seems to have been a complete failure of both the victim and the buddy to grasp the implications of

continuing such a deep and dangerous dive with the unit's alarms sounding. Whether this was a matter of complacency or a lack of knowledge is difficult to determine from the reports received. Buddies conducting such dives have a responsibility to understand the functioning of each other's equipment and the meaning and implications of alarms and to 'call the dive' if things are not progressing correctly. From our experience, we have seen a progressive increase in acceptance of risk within such groups as they have successfully carried out dives without incidents. While this team did have a 'dive supervisor' and dive plans, these are of little consequence if the supervisor is unable to vet the diver's equipment is correct and fit for the task. Some agencies have advocated commonality of equipment and gas to overcome this problem. Furthermore, divers who operate far offshore in slow boats, distant from retrieval services must realise that in the event of a serious accident there is little hope of timely medical support being available. Accepting such risk is a matter of personal choice, providing that everyone involved is actually aware of the risks and the consequences of an accident.

The problem of distinguishing CAGE and post-mortem off-gassing continues to make interpretation of autopsy findings difficult. CT scan offers great promise; however, correct interpretation depends on accurate reporting of the location (arterial, venous, soft tissue and joint) and rough volume of the gas. Gas in joints and tissues suggests off-gassing or later decomposition. Gas due to decomposition tends to start in the liver. The CT scan should be performed within eight hours of death.

As with any uncontrolled case series, there were inevitable limitations and uncertainties associated with our investigations. These included:

- Incomplete case data. Fatalities were sometimes unwitnessed, and reports provided by any witnesses and by police varied in their likely reliability, as did their content and depth, and the expertise of the investigators.
- Unreliability of some autopsy reports because of the difficulty of determining the presence of CAGE in the absence of relatively prompt post-mortem CT scans, and the inability to detect evidence of cardiac arrhythmias, among other factors. Care must be taken to critically examine the available evidence and minimise speculation when determining the likely disabling injury.
- Classification of cases into a sequence of four events (trigger, disabling agent, disabling injury, cause of death) requires a single choice for each event which may omit important factors in some cases.
- Limited annual case data; 19 deaths is too small a number to determine reliable trends.
- In some coronial jurisdictions, this research team has been unable to access witness reports and this limits our ability to examine cases in as much detail as we believe is necessary.

Conclusions

There were 19 reported diving-related fatalities during 2007, including nine deaths while snorkelling and/or breath-hold diving, eight while scuba diving, one while using a closed-circuit rebreather and one while using surface-supply breathing apparatus.

Causal factors associated with these deaths included: inexperience; diving in adverse conditions; cardiac disease or other co-existing illnesses and diver error. With snorkellers, the likely disabling injuries were asphyxia and cardiac causes. In scuba divers, the disabling injuries appear to have been asphyxia, CAGE, cardiac causes and immersion pulmonary oedema.

Factors that may reduce mortality in the future include better supervision of inexperienced and older snorkellers; improved medical screening of older divers; better education of prospective and active divers about potential health risks; careful buddy monitoring and the wearing of suitable buoyancy vests.

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Conflict of interest: John Lippmann is the Executive Director of Divers Alert Network (DAN) Asia-Pacific. DAN is involved in the collection and reporting of dive accident data and provides evacuation cover and dive injury insurance to recreational divers.

Funding: This study was funded by DAN Asia-Pacific.

Acknowledgements

We acknowledge Monash University National Centre for Coronial Information for providing access to the National Coronial Information System (NCIS), State and Territory Coronial Offices, various police officers, dive operators and divers who provided information on these fatalities.

Submitted: 06 December 2011
Accepted:15 June 2012

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Workshop report

The use of deep tables in the treatment of decompression illness: The Hyperbaric Technicians and Nurses Association 2011 Workshop

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Abstract

(Bennett MH, Mitchell SJ, Young D, King D. The use of deep tables in the treatment of decompression illness. *Diving Hyperbaric Medicine*. 2012;24(3):171-180.)

In August 2011, a one-day workshop was convened by the South Pacific Underwater Medicine Society and the Hyperbaric Technicians and Nurses Association to examine the use of deep recompression treatment tables for the treatment of decompression illness in Australia and New Zealand. The aim of the workshop was to develop a series of consensus statements to guide practice around the region. The workshop chose to focus the discussion on the use of 405 kPa (30 msw) maximum depth tables using helium-oxygen breathing periods, and covered indications, staffing and technical requirements. This report outlines the evidence basis for these discussions and summarises the series of consensus statements generated. These statements should assist hyperbaric facilities to develop and maintain appropriate policies and procedures for the use of such tables. We anticipate this work will lead to the formulation of a standard schedule for deep recompression to be developed at a future workshop.

Key words

Recompression, decompression illness, decompression sickness, heliox, treatment, hyperbaric facilities, safety, meetings

Introduction

This one-day workshop, jointly run by the South Pacific Underwater Medicine Society and the Hyperbaric Nurses and Technicians Association (HTNA) was held in August 2011. At the workshop, we proposed a series of statements concerning the use of deep treatment tables for decompression illness (DCI). These statements were broken up into three sections (medical, nursing and technical), each introduced by a formal presentation from an expert in the appropriate discipline. Following the presentation of each proposed statement, the joint chairs moderated an open discussion designed to modify the statement as required and seek a consensus. Following agreement on each statement, we moved to the next. The aim was to build through consensus a logical, comprehensive approach to the use of deep treatment schedules. In this report, the medical, nursing and technical background material is reported first, followed by 17 concensus statements with summaries of the discussions on each.

Summary of the evidence and medical considerations

For over a century, the 'standard of care' treatment for DCI has been recompression.[1] Early success using air breathing during recompression to the 'depth' (pressure) of the incident dive was enthusiastically reported in comparison to the previously common approach of masking symptoms with alcohol and morphia until they receded.[2] The use of formalised 'deep' treatment tables really begins with the development of US Navy (USN) Treatment Tables 1 to 4 by Van der Aue and others.[3] These tables were formally adopted by the USN in 1945 and were the preferred approach for the treatment of DCI until the 1960s. Over time, however, it became clear there were many problems with the use of long air recompression tables and in the 1950s and 60s, following the work of Behnke and others in the USN, the use of relatively low-pressure, short oxygen (O_2) tables achieved widespread acceptance. Today, the most commonly used recompression schedules for DCI worldwide involve compression to 284 kPa (18 metres' seawater (msw) equivalent) with 100% O_2 breathing (F_iO_2 = 1.0), followed by decompression according to the USN Treatment Table 6 (USN TT6) (see footnote) or the very similar Royal Navy Table 62 (RN62).[3,4] Several variations of these tables exist. The Divers Alert Network (DAN) reports suggest that about 80% of initial recompressions are delivered on one of these schedules, while less than 1% were clearly identified as 'deep' tables (0.7%) and 8% were simply classified as 'other'.[5]

The O_2 tables are highly successful, with resolution rates approaching 100% in some hands. The likelihood of success is related to the time delay to recompression – at least at the extremes. For example, Thalmann reported 97% resolution with prompt therapy, dropping to about 80% if treatment was

Footnote: The figures displaying the various treatment tables discussed at the Workshop are available separately to this article on the Journal and Society websites in a pdf file entitled: *Treatment tables for the Deep Tables Workshop*.

delayed for hours rather than minutes.[6] Outside the military sphere, Sayer et al reported 89.5% complete resolution or major improvement in a series of 194 Scottish divers.[7]

DEEP TABLES

'Deep' tables involve compression to pressures greater than 284 kPa (18 msw), the pressure beyond which it is unsafe to continue breathing 100% O_2. Two general forms exist, defined by the nature of the breathing gas. The first involves air or O_2-enriched air ('nitrox'), two examples being the USN TT4 and 6A, which involve excursions to 608 kPa (50 msw) whilst the patient breathes air.[3] The second involves the use of helium/oxygen (heliox) breathing mixtures. Probably the most commonly used of these is the Comex 30, which involves compression to a maximum pressure of 405 kPa (30 msw) while the patient breathes a 50:50 mixture of heliox. At the workshop, the participants defined the scope of the discussion, and it was quickly agreed that the primary interest was in the appropriate use of heliox tables, and this is reflected in the account that follows.

THE EVIDENCE

Vann et al. in a recent review of the treatment of DCI, acknowledge that 284 kPa O_2 tables have become the *de facto* standard of care, summarising the evidence for using deep tables thus: *"...supporting evidence is weak for depths greater than 18 m*[sw] *for initial recompression without a demonstrated need to go deeper, and no benefit has been shown in animal studies. Many recompression strategies ranging from pressures of 1.9–10.0 bar* [192 kPa to 1.01 MPa] *exist, but there are no human outcome studies for comparison of efficacy*".[8] Given this flimsy basis in support of deep tables, why are they still used? There are two principal arguments in favour of such tables. First, both physics and *in-vivo* animal experiments confirm that compression to greater pressure results in a more rapid reduction in bubble volume, particularly when heliox mixtures are employed.[9–11] Second, helium has a low lipid solubility, which may assist with denitrogenation of the tissues as there will be lower volumes of gas available for ingress into bubbles. Hyldegaard et al. have demonstrated more rapid resolution of bubbles with heliox and a transient increase in bubble size on compression while breathing 100% O_2.[10,11] They concluded: "*The clinical implication of these findings might be that heliox 50:50 is the mixture of choice for the treatment of decompression sickness.*"

Other animal model evidence has not shown a clear advantage for either heliox or deep recompression. Arieli et al compared DCS in a rat model using compression on O_2 (284 kPa) versus heliox (304 kPa) following a deep 'trimix' dive.[12] When treatment was delayed by 5 min after a provocative dive, the difference in death rate (25% with 100% O_2 versus 20% using heliox) was not statistically significant. In a dog model of cerebral arterial gas embolism, Leitch et al concluded that there was no advantage in preceding 284 kPa O_2 treatment with compression to 608 kPa on air.[13] They were also unable to demonstrate improved recovery in a dog spinal DCS model when the pressure was increased as the partial pressure of O_2 was held constant.[14]

The clinical evidence for the use of deep tables is largely anecdotal. In 1990, Thalmann described a number of cases where symptoms and signs refractory at 284 kPa resolved on deeper exposure.[15] In 1997, Shupak, in an historically controlled series of divers treated for spinal DCS, demonstrated no difference in outcome between USN TT6 or a heliox protocol.[16] However, this study was biased against the heliox treatment protocol because the severity score at presentation was significantly worse for that group ($P < 0.001$). Interestingly, of the 17 patients who were treated with the use of the O_2 tables, five deteriorated after the initial recompression. The authors also noted that two heliox patients had extensions of the Comex 30 and two further heliox patients went into saturation treatments, while in the other group, nine patients required an extended USN TT6. Shupak concluded: "*The results suggest an advantage of helium oxygen recompression therapy*".[16]

Following this report, there have been at least two attempts to perform randomised studies. Drewry et al reported in a meeting abstract on the first 88 patients enrolled in a trial comparing two complex algorithms based on heliox and nitrox breathing gases.[17] Patients in both groups started with compression to 284 kPa (18 msw) and could progress to 405 kPa (30 msw) on 50% O_2 if incompletely resolved after two 20-minute O_2 breathing periods. The odds of multiple recompressions was lower with the heliox table compared to the nitrox table (RR 0.56, 95% confidence interval (CI) 0.31 to 1.00, $P = 0.05$). Unfortunately, because of a failure to recruit divers early, the study was abandoned.[18] In 1999, a draft protocol by Hink to test the Comex 30 table against the standard USN TT6 never commenced formal recruitment.[19]

SUMMARY OF CURRENT OPINION

Little formal discussion has occurred over the last decade, with no clear consensus among experts. In 1998 Gorman and Moon summed up the situation as follows:[18]

Gorman: "*The 1995 attempt at consensus went no further than the 1990 attempt at consensus, which was pretty much the same as the 1979 consensus, and my advice then was, as it is now, get the old document, white out the date and just change* [it]."

Moon: "*The idea of using heliox as part of a recompression has been around now for 10 or 15 years, and slowly but surely, based on anecdotal reports and personal experience, it is becoming the de facto standard of care, unfortunately, I believe, without the necessary data. It may well be correct that helium-oxygen is more efficacious than oxygen or nitrox, but I think the danger of accepting this notion without the proper data is that a tremendous expense to chambers*

around the world would be incurred. I have seen a number of severe neurological bends referred to our medical centre after having received a treatment somewhere else, which either did nothing or actually appeared to make the patient worse. Those patients uniformly responded to [oxygen] *recompression at our medical centre. I do not really understand why, it must have something to do with the natural history of the disease, but treatment a day later often is more efficacious than the initial treatment. If we had used helium-oxygen for those second treatments, we would be enthusiastically touting helium-oxygen. So, we must keep an open mind on heliox, but not accept it until the necessary observations have been made.*"

In 2011, little has changed. What follows is a pragmatic attempt to combine the Australasian experience and make some statements designed to guide those who may consider using deep tables in their clinical practice.

Some tables under consideration

There are many 'deep' tables from which to choose. Given that 100% O_2 breathing is unsafe beyond about 284 kPa, and that inert gases other than nitrogen and helium are not generally available (or necessarily useful), there are basically two approaches to deep tables, as noted above. For the workshop, the following representative tables were chosen, on which the participants could base their comments.

COMEX 30 (and COMEX 50)

These tables have a surprisingly difficult-to-define provenance. Since the workshop, it has been established that the Comex 30 table is an adaptation by Dr Xavier Fructus of an older nitrox table developed by Dr Barthelemy at the French Navy diving facility (GERS) in the late 1950s. The Comex table appeared for the first time in 1974 using either 50:50 nitrox or heliox (Imbert JP, personal communication 2012). The final version of the Comex 30 heliox table appeared in the 1986 Comex medical book. Since then it has been modified by many users, so that multiple similar versions are in use around the world. Today, there are many 30m heliox tables from which to choose.

Essentially the Comex 30 table involves an initial compression to 405 kPa (30 msw) for 60 minutes breathing a 50:50 heliox mixture, followed by decompression on the same mixture, with stops at 344 kPa (24 msw), 304 kPa (20 msw) and 223 kPa (12 msw), (total time 450 min). The Comex 50 table is very seldom used. It involves a period of 80:20 heliox breathing at 608 kPa (50 msw) before decompressing to 405 kPa (30 msw) and proceeding much as for a Comex 30 table.

Two versions of a Comex 30 in use in Australian hyperbaric units are shown in the pdf on the websites. These give instructions for locking in a second attendant on reaching 284 kPa (18 msw) during decompression. One of these tables is designed to convert a USN TT6 to a 405 kPa (30 msw) heliox table after failed symptom resolution at 284 kPa (a similar approach to the RNZN 1-alpha discussed below). Finally, an example of a 608 kPa (50 msw) modified Comex heliox table (developed by Dr. Robert Wong for the Fremantle Hyperbaric Service) is also shown on the websites.

RNZN 1-ALPHA

This table involves 50:50 heliox breathing initially at 284 kPa (18 msw), progressing to 405 kPa (30 msw) if there is less than 80% resolution after a period. It resembles a Comex 30 table but with an option to go no further than 18 msw if there is a good response, and with the shallowest stop pressure at 192 kPa (9 msw) instead of 223 kPa (12 msw). An additional feature is that all 'air' breaks are on 80:20 heliox.

HAWAIIAN TABLES

These deep air-breathing tables are unique to Hawaii.[20] They utilise an initial deep 'spike' to either 962 kPa (280 fsw; 85 msw; TT280), 780 kPa (220 fsw, 67 msw; TT220), or ~608 kPa (160 fsw, 49 msw; TT160) using nitrox mixes of 65:35 and/or 50:50. The Hawaiian physicians claim these tables are more successful than the 'standard' 284 kPa tables and some version of these tables is employed for 90% of DCI treatments. The rationale is that they take advantage of pressure to reduce bubble size and enhance dissolution, followed by a slow, staged decompression while providing therapeutic hyperbaric O_2, eventually transitioning to 100% O_2 at 284 kPa, and then a more gradual staged decompression rate compared to USN tables.

US NAVY TREATMENT TABLE 6A (USN TT6A)

This table was originally proposed for the treatment of arterial gas embolism on the basis that a high pressure spike to 608 kPa (50 msw) at the start would promote bubble resolution through Boyle's law.[3] After a period of 30 min (which includes the compression time) breathing air at 608 kPa (50 msw), the patient is decompressed to 284 kPa (18 msw), where a standard USN TT6 is commenced. There has been no clear validation of this table (see above) and it is now rarely used.

USN AND RN DEEP AIR TABLES

Both navies have published a series of air tables with deeper excursions than 284 kPa (18 msw).[3,4] They are largely historical, although they are still employed occasionally for resistant cases, particularly in facilities that have the ability to convert to a saturation protocol. They may also be used in unusual situations where O_2 is not available for recompression. The series includes:

USN TT2A (RN52): 11 hour table to 608 kPa (50 msw) (no O_2 available);
USN TT3 (RN53): 19 hour table to 608 kPa (50 msw) on air, then O_2 breathing at 284 kPa (18 msw);
USN TT 4 (RN54): 38 hour table to 608 kPa (50 msw) then O_2 breathing at 284 kPa (18 msw);
RN55, 72, 71: 43- to 48-hour tables with extended stops when no O_2 is available.

Nursing perspective on the use of deep tables

A small survey taken around Australia on nursing aspects of the use of deep treatment tables was reported. Thirteen nurses from four facilities where deep tables had been used responded. All used the Comex 30 schedule.

1. Were you looking forward to doing a Comex 30 treatment? About half said 'no' and cited the length of time in-chamber and concern about performance at depth due to nitrogen narcosis, with a sick patient in a small treatment area as the common reasons for this. The other half said they were looking forward to it, citing the opportunity to be involved in a rare experience, to practise what they had trained for and extend their deepest treatment table experience. A single responder was indifferent about such treatments.

2. After doing a Comex 30 table, what were your feelings about doing further Comex 30 tables? There were mixed responses and the strong implication was that the experience could be either strongly positive or negative. Some were now more confident to undertake further such treatments, while others were not at all keen to repeat the experience.

3. Describe any incidents during the treatment table that made it more difficult or challenging. Few responses concerned incidents directly related to patient care. Two respondents found the treatment highly challenging caring for critically ill, ventilated patients (near drowning plus DCI). Two noted the need to concentrate carefully on a single task at any one time because of the effects of nitrogen narcosis. Two also remarked on the problems of working in a confined space for such a long period of time, while one reported being very fatigued and having trouble staying awake. Finally, one nurse reported difficulties with equipment running out of battery power during the treatment.

4. Did you suffer any ill effects during or after the treatment? Four nurses reported no ill effects, while the remaining nine had some problems to report. Eight reported fatigue after the treatment for one to two days, described by one as very similar to 'jet lag'. Three nurses complained of chest pain or tightness with cough, which was attributed to O_2 toxicity or a long period of breathing dry gases. One nurse complained of feeling nauseated while on O_2.

5. If you did suffer from ill effects were these reported to anyone? Four of the nine nurses who described ill effects had reported these to the medical officer in attendance. Several remarked that fatigue was expected and did not warrant reporting, while the single episode of nausea was not reported as it resolved on ascent.

6. Did you feel that you were at increased risk relative to attending an RN62? Despite the majority of respondents reporting some ill effects, only six agreed with this proposition, citing the consequences of increased depth and length of this table. The remaining seven felt they were at no increased risk and one commented that she was confident that all safety requirements would be adhered to, thus keeping risk to a minimum.

7. What was the outcome for the patient? Six of the 13 patients treated were fully recovered and four almost fully recovered. Three patients had only partial improvement.

8. Did you use the toilet during the Comex 30 table? While 11 nurses urinated as required and freely, two did not urinate at all during the table due to embarrassment. These respondents worked in a chamber with no toilet available at pressure, and were required to use a bedpan. It was observed that, at times, nurses deliberately avoided liquids prior to compression in order to avoid this embarrassment.

9. Did you feel that you had adequate support from the outside staff? All respondents reported that the outside staff were very helpful and attentive.

10. Please let us know if you have any other thoughts about the Comex 30 treatment table. A number of free-text comments are paraphrased here:

- I dislike being on O_2 for so long as it leads to cough and chest pain.
- I had more concern for the patient than myself.
- I would prefer to split the duration between two attendants.
- It was a good experience!
- This table is much better if it is not late at night.
- It was good to be involved; all part of job.
- It was a unique experience, but I dislike the "endless" O_2; I will do it in the future if required. It was challenging with a sick patient, but there was a good outcome.
- The table would be more comfortable with a better-designed chamber and, in particular, a toilet.
- Outcomes for the patient are good, and I support the use of the table, but have reservations about the depth and time a single attendant spends inside.

While many issues are raised by this small survey, three were of particular interest to the nursing staff. First, it was noted that the usual staffing for these tables is a single doctor, technician, outside nurse and attendant. There may be a good case for a second attendant to lock in at some point and relieve the first attendant. The second relates to

professional competencies. Many remarked that there were no such competencies specifically relating to deep tables, and this situation was contrasted with other areas, such as the treatment of ventilated patients. Finally, there was great interest in discussing the safety of such treatments for inside attendants. The workshop then generated some related consensus statements.

Technical aspects of the use of deep tables

There are a number of identifiable risks arising from the use of these tables. Some of these are considered below.

STAFF DECOMPRESSION

Computing appropriate decompression schedules for the attendant is problematic. While all recompression tables rely on approximations and empiricism, the more routine exposures have the great advantage of history on their side. In any busy hyperbaric facility there will be hundreds of staff decompressions every year, such that the incidence of even relatively rare complications (e.g., DCS) can be estimated with some accuracy. Deep tables are rarely required and our collective experience is little more than a handful of cases in a year. The true risks may take many years to emerge with any accuracy, and staff are at risk in the meantime. This is even more so when considering extended tables, those converting from 18 msw tables, or those where tables are 're-started' following relapse on decompression. It would be very difficult to truly validate these schedules in an ethical manner. For this reason, decompression schedules are generally very conservative in these situations. From time to time, deep tables will need to be aborted unexpectedly, and plans must be in place to manage the decompression of the attendant under such circumstances.

ENSURING THE CORRECT GAS IS DELIVERED

Each of these deep tables involves several gas switches at differing pressures. At each switch, there is a risk of delivering an incorrect gas mix which could lead to O_2 toxicity or DCS. Several methods exist for checking the gas mix at these times and a safe treatment cannot be delivered without careful consideration of what combination of checks is likely to work best for the individual facility. Examples of such checks include noting changes in the gas-flow tone or register of the voice and physically double-checking the O_2 content of gas. Any safe facility will have staff appropriately trained in switching procedures and a regimen of regular competency checks.

GAS SUPPLY

Deep treatment tables consume large volumes of gas. The technician must ensure there is ample gas available to safely complete treatment with a significant reserve. Where possible, the use of hoods should be avoided in favour of demand-style regulators (e.g., Scott masks) or closed/semi-closed anaesthetic circuits.

Table 1
Example calculation for gas supply requirements

Calculate the amount of O_2 required for a USN TT6 (RN62) (without extensions) for one patient and one attendant. This requires four separate equations [2–5] due to the linear decompression stages and the two different treatment pressures (284 kPa (2.8 ATA) and 192 kPa (1.9 ATA)).

For the 2.8 ATA section: *3 times 20 min O_2 breathing periods.*
2.8 x 60 (Mins) x 15 (L min^{-1}) x 1.25 (SF) = 3,150 L O_2 [2]
For the 2.8 – 1.9 ATA section: *As the decompression is linear, an average of the absolute pressure over the 30 min is appropriate (i.e., 2.35 ATA).*
2.35 x 30 x 15 x 1.25 = 1,322 L O_2 [3]
For the 1.9 ATA section: *2 times 60 minute breathing periods for the patient and the attendant breathes O_2 for the last 30 min*
1.9 x 150 x 15 x 1.25 = 5,343 L O_2 [4]
For the 1.9 ATA to surface pressure section: *As the decompression is linear, an average of the absolute pressure over the 30 minutes is appropriate (i.e., 1.45 ATA). The attendant needs to breath O_2 for the duration of this section, therefore, time is be calculated at 60 min.*
1.45 x 60 x 15 x 1.25 = 1,632 L O_2 [5]

Total O_2 required = 11,447 litres

Table 2
Volumes of treatment gas required to conduct commonly used 'deep' treatment tables; FHHS 50 – Fremantle Hospital Hyperbaric 50 msw schedule; USN6–Cx30 – initial USN TT6 converting to Comex 30 if poor response

Treatment table	Pressure (max., kPa)	Time (hr:min)	Volume of gas (L) (Heliox or Nitrox)		
			50:50	20:80	40:60
USN TT1A	304	6:20	7,358	--	--
Comex 30	304	7:40	9,281	--	--
FHHS 50	507	9:20	14,578	3,496	12,984
USN6–Cx30	304	9:35	14,100	750	--

How much gas might be used in a typical treatment? Calculation of the volume of gas required can be made by multiplying the atmospheric pressure inside the chamber (P, measured in Atmospheres Absolute, ATA) by the time spent at that pressure (T, min) by the volume of gas used by the patient(s) and attendant(s) per minute ($\dot{V}$, L min^{-1}) and by an appropriate safety factor (SF). That is:

Volume required = P x T x $\dot{V}$ x SF [1]

The volume of gas used by the patient (and attendant) is assumed to be 15 L min^{-1} for a demand-supply mask (e.g., Scott mask; requirements may differ for alternative breathing systems). The 'slides' from one pressure to another are estimated using the pressure at the midpoint of the slide. The safety factor recommended is 1.25. That is, multiplying the calculated expected volume usage by 1.25. An example gas calculation is shown in Table 1. Using the formula above, Table 2 shows the volume of gas(es) required to complete some of the tables commonly used in Australia.

INCREASED RISK OF O_2 TOXICITY TO BOTH THE PATIENT AND THE ATTENDANT

During deep tables, the patient is exposed to a high PO_2 for relatively long periods, and, therefore, is at risk for both pulmonary and central nervous system O_2 toxicity. As with all recompression therapy, the risks and benefits need to be carefully weighed. During decompression, the attendant(s) also spends significant periods breathing at high PO_2. The true incidence of toxicity is unknown (for similar reasons discussed above in regard to DCS) but cases have been reported. This is one of the advantages of considering a second attendant to be locked in during the treatment schedule. Facilities will need to have carefully reasoned procedures for dealing with both patient and staff O_2 toxicity, and should practise emergency procedures with regularity in anticipation of such events.

ATTENDANT FATIGUE

The sole attendant is not only at risk of both nitrogen narcosis early in the treatment (see below), but also fatigue due to the extended treatment time. The operating procedures of the individual unit must allow for any local award considerations and rules regarding working hours. There are several related issues that can only be addressed at a local level. Mandated work breaks will need to be addressed, both within normal working hours and after hours.

In practice, it may be impossible to relieve the inside attendant, while the available 'relief' staff may not be suitably trained and qualified to act as outside attendants. Indeed, there is also the question of the competence of medical officers to act as outside attendants. Some units have implemented specific competencies for their medical staff in order that they may step into roles as outside attendant, inside attendant or even technician, as the need arises.

CHAMBER OPERATOR FATIGUE

Similar issues arise with the potential for reduced vigilance and performance of the lone technician during a long, deep table. There are several critical aspects to the safe conduct of these tables, and arguably, a single attendant may be adversely affected, particularly if the treatment begins in the evening after an already full day's work. Local award considerations need to be addressed and consideration given to making a second technician available at a suitable time during the conduct of the table. With respect to both the attendant and the technician, there will be considerable cost implications for the provision of 'back-up' staff.

NITROGEN NARCOSIS IN THE ATTENDANT

All deep tables require the attendant to breathe air at a pressure sufficient to induce some degree of nitrogen narcosis. Procedurally, someone in the team must be identified as the 'decision-maker' and, ideally, this person should not be exposed to a high PN_2. There may be legal implications for any individual or facility that contemplates putting the decision-maker into such a position. It is unclear what can mitigate this situation, apart from 'doubling-up' all personnel involved in the treatment at considerable cost. It may be possible to modify the breathing system to allow heliox breathing for the inside attendant(s), or to introduce testing procedures to ensure 'tolerant' individuals are chosen for such tasks. We know of no facilities where either of these options has been put into practice.

EQUIPMENT ISSUES

Any in-chamber equipment must perform to the manufacturer's standard while under pressure; however, most medical equipment will require some modification in order to achieve this. This is particularly so in relation to mechanical ventilation and drug delivery systems such as pumps and drip counters.[21–23] A thorough system for risk assessment is required, involving the local clinical engineering (or biomedical) department. Any equipment not tested adequately for safety and performance under the relevant conditions should be banned from the chamber.

EMERGENCY PROCEDURES

A guiding principle of safe chamber operation is the existence of appropriate and practised emergency procedures (EPs). Given the rare use of these tables, and the increased risks inherent in going deep and long, this is particularly relevant in relation to them. EPs must be developed to cover all the identified risks discussed above. Ideally, the local occupational health and safety officers should be invited to participate from an early stage to ensure the ultimate adoption within the hospital facility of these procedures. These EPs must be reviewed and practised at regular intervals, and all such activity should be carefully logged.

Workshop consensus statements

The workshop was opened for discussion based on a series of statements concerning the medical application of deeper tables for the treatment of DCI. Each statement was generally accepted after discussion and modification, and the debates are summarised following each statement.

STATEMENT ONE – SCOPE OF THE WORKSHOP

This workshop will limit the consideration of deeper treatment tables to those involving periods of heliox breathing at 405 kPa (30 msw) and 608 kPa (50 msw) only.

Deeper nitrox (including air) breathing tables are used extremely rarely and no participant had used such tables for many years. Therefore the focus should be on the use of heliox tables at 405 kPa (30 msw) and 608 kPa (50 msw).

STATEMENT TWO – EVIDENCE FOR 'STANDARD OF CARE' USE

The evidence supporting the use of deep recompressions using heliox as a treatment gas is relatively weak. Notwithstanding the following discussion, these treatments cannot and should not be considered a 'standard of care' for relevant DCI cases.

There was broad agreement with the summary evidence as presented above. While both experience and evidence suggests there is a place for the use of these tables, there is no justification for the adoption of these tables as 'standard of care' in any particular clinical situation.

STATEMENT THREE – SITUATIONS WHERE DEEP HELIOX TABLES MAY BE INDICATED

Deep treatment tables may be indicated for:

Significant neurological DCI where a period of oxygen breathing at 284 kPa (18 msw) has not resulted in improvement of the clinical condition; OR at the initial presentation of serious neurological DCI; OR other life threatening, serious, or rapidly progressive presentations.

Some time was spent discussing the potential indications for these tables. It was agreed that:

- Appropriate personnel, experience and equipment (as defined later in the workshop) were a necessary pre-requisite before considering the use of these tables.
- No definitive list of indications could be generated from the evidence, and no statement should attempt to restrict the use of these tables. The clinician should be able to assess each presenting diver on an individual basis, and to use their own clinical judgement as to the appropriate therapy. This statement is a guide to clinical practice rather than a statement of 'standard of care' or a recommended clinical pathway.
- Serious neurological presentation was overwhelmingly the most common situation where the use of a deep heliox table should be considered.
- There was no consensus on the relative merits of using a 284 kPa (18 msw) O_2 breathing period as the primary approach, with conversion to deep heliox if the response is inadequate (as with the RNZN 1-alpha table), or a deep heliox table as the primary recompression schedule.
- There was strong support for allowing that other serious presentations may also be indications for a deep heliox table at the discretion of the treating physician.

STATEMENT FOUR – WHICH TABLE?

There is no good evidence for recommending a particular deep treatment pressure. Consideration of 405 kPa (30 msw) vs 608 kPa (50 msw) (or other treatment pressures greater than 284 kPa (18 msw)) must be undertaken by each unit based on experience and logistic considerations.

While the experience of the participants was overwhelmingly with the use of the 'Comex 30' table in its various forms, there was no clinical evidence to support the choice of any particular heliox-breathing schedule. Many experienced clinicians made the point that experience with the chosen table was invaluable, while logistical support was a vital factor in making this decision.

STATEMENT FIVE – USE OF REPEAT DEEP EXPOSURES

There is no indication for a second deep treatment table in the event of incomplete symptom resolution following the first.

There was unanimous agreement there was no indication for a second deep treatment for residual symptoms and signs following an initial recompression. Administering more than one such treatment within a short space of time carries logistic difficulties in most clinical facilities, and there is no good evidence to support such a practice.

STATEMENT SIX – INSIDE ATTENDANT TRAINING

Any deep treatment table should involve the attendance in the chamber of appropriately trained staff.

There is no advantage attached to mandating a particular set of requirements for training as these are site specific. Each facility intending to use deep treatment tables should develop appropriate training modules and procedures to suit their own operations. Neither is this statement intended to imply that inside attendants must have entry qualifications in any particular discipline.

STATEMENT SEVEN – MEDICAL STAFFING

The minimum medical staffing for a deep treatment table is one experienced hyperbaric medical officer (HMO) dedicated to the immediate supervision of that treatment. Consideration should be given to calling on a second medical officer if the supervising HMO is required to be compressed.

An experienced HMO is required in attendance at a deep treatment table. While there was debate about the need for a second HMO trained in diving medicine if the primary HMO is required to enter the chamber, most experienced physicians considered there was no justification for a formal 'second call' roster to be developed. This situation occurs so rarely that it is best addressed by each unit individually.

STATEMENT EIGHT – NURSING/ATTENDANT STAFF

The minimum number of trained chamber attendants for a deep table is one inside attendant and one outside attendant.

The preferred number of trained chamber attendants for a deep table would allow a second inside attendant to take over care of the patient during the table.

The staffing level for chamber attendants during a deep table varies greatly between facilities. While it is highly desirable to reduce fatigue and the incidence of complications due both to pressure exposure and lengthy O_2 breathing periods, it may not always be logistically practical to ensure that an attendant change over can be achieved safely. Each facility should consider the possibility of such a change over. This is the preferred staffing arrangement.

STATEMENT NINE – HYDRATION AND TOILETING ARRANGEMENTS

The inside attendant in a deep treatment must ensure they maintain adequate fluid intake both before and during the exposure. Acceptable toileting facilities must be provided.

This requirement was unanimously agreed. While it is acceptable that some chambers will not have a standard toilet available at depth, there must be adequate facilities in place to ensure privacy and hygiene to allow comfortable and safe toileting.

STATEMENT TEN – ALTITUDE AND EXERCISE AFTER DEEP TABLES

The chamber attendant should not fly for at least 24 hours after a deep treatment table, and not undertake strenuous exercise (e.g., jogging, weights session, cycling) for 12 hours after such a table.

There is little evidence to guide such recommendations, and 'strenuous exercise' is difficult to define. Individual facilities are encouraged to refer to published standards with regard to altitude exposures (both flying and terrestrial) following individual treatment tables, while each facility should develop a policy regarding the permissible level of exercise following such exposures.

STATEMENT ELEVEN – ATTENDANT TIME TO SUBSEQUENT COMPRESSION

The chamber attendant should not be required to be compressed again for a minimum of 24 hours after completing a deep treatment table.

While this statement was widely accepted, it was allowed that, in the event of two attendants sharing the exposure (as recommended in statement eight above), a shorter period may be permissible for the second attendant. This will depend on the point at which the change over occurs and is at the discretion of individual facilities.

STATEMENT TWELVE – GAS SUPPLY

The minimum safe gas supply to allow for the performance of a deep table is to be calculated, and the correct volume of gas is to be immediately available and a written note made to that effect before starting the treatment.

The oxygen content of any heliox mixtures should be measured prior to use (see Table 1 above).

STATEMENT THIRTEEN – CHAMBER OPERATOR AVAILABILITY

The minimum safe technical staff level for a deep table is two.

The presence of two technicians was considered to be highly desirable, but some argued that such a provision would be very difficult in practice. After discussion, a show of hands was overwhelmingly in favour of including this statement.

Such an arrangement could be achieved 'ad hoc' rather than by a formal 'second on-call' roster. Two operators would not be required for the entire table, but rest relief or a change over as mandated by local practice rules was entirely appropriate. A number of attendees suggested that the inability to locate a second operator to provide such relief was a good reason to pursue an alternative, shorter table rather than persist with a single operator.

STATEMENT FOURTEEN – CHANGE-OVER TIME FOR INSIDE ATTENDANT

While it is acceptable practice to require a single attendant to complete a deep treatment table, if a change of attendants is considered necessary or desirable, a suitable time to make the change is on arrival at 223 kPa (12 msw) for a Comex 30 heliox (or similar) table, and on arrival at 284 kPa (18 msw) for a Comex 50 table.

These times are chosen on the basis that they are the points at which the first attendant is required to breath 100% O_2, and is therefore both at risk of O_2 toxicity, and less physically able to attend the patient. The second attendant will have minimal decompression obligation (particularly so with the 405 kPa (30 msw) tables) and will have a reduction in the time to recompression for future work.

STATEMENT FIFTEEN – ATTENDANT ON OXYGEN

The attendant(s) are required to hold on their mask during oxygen breathing periods during deep treatments.

While it is possible that any central nervous system toxicity will terminate equally as rapidly whether the O_2 mask is removed or not, the workshop was unanimous in the opinion that it remained good policy not to have the attendant use a mask strapped onto the head for decompression. A secondary advantage of this practice is that a dropped or removed mask, whether owing to fatigue or inattention, would bring the early attention of the operator and outside attendant to the fact that there may be a problem inside. If two attendants are inside, only one of whom is required to breathe O_2, then strapping to the head would be appropriate, if that was preferred by the individual.

STATEMENT SIXTEEN – GAS SWITCHING

Gas switching periods should be made safer by close, alarmed monitoring systems to ensure safe transitions.

Gas switching is a time of increased risk in the performance of all deep treatment tables. While there are physical signs of successful switching (e.g., voice timbre or gas-flow pitch) these are generally less reliable than appropriate monitoring systems with alarm limits. There are a number of alternative

monitoring systems available and the choice will depend on local considerations. Alarmed monitoring is mandatory for the safe conduct of deep treatment tables using heliox mixtures.

STATEMENT SEVENTEEN – ATTENDANT DECOMPRESSION FOLLOWING ABORTED DEEP TABLE

In the event that a deep treatment needs to be aborted, the attendants must have another chamber available (and to which they can transfer under pressure) in order to complete any decompression obligations.

It is acceptable that any attendant so affected can complete their decompression without themselves being attended.

There is a practical limit to the support that can be provided during the use of a deep table, and it is unreasonable to expect a third attendant to be on call in the unlikely event that a table is aborted, leaving two attendants with decompression requirements. In this case, it is reasonable to allow the attendant to decompress alone with observation only from outside the chamber. "Another chamber" here does not mandate a second, independent vessel, but that an independent compartment within the same vessel would be acceptable. What is required is the ability to more rapidly decompress the patient in the case of an abort, while still protecting the original attendant from decompression injury by allowing the planned decompression procedure in another chamber/compartment.

Conclusions

Deep treatment tables resembling the Comex 30, which utilise pressures higher than 284 kPa and heliox breathing, are used sporadically in Australia and New Zealand. There is sufficient evidence of efficacy to justify this practice, but insufficient evidence to establish such tables as a 'standard of care'. Nor is there an evidential basis for choosing one deep treatment regimen over another.

Hyperbaric units undertaking deep treatments must be appropriately equipped and staffed. 'Appropriately equipped' implies the presence of the required gas delivery and monitoring systems, sufficient supplies of all relevant gases, toileting facilities, and an externally accessible compartment into which attendants can transfer under pressure for decompression independent of the treatment compartment, if there is a requirement to abort the treatment in an emergency. Deep treatments should be attended by medical, nursing, chamber attendant and technical staff who are trained and experienced in their implementation.

The minimum staffing for a deep treatment is one medical officer, two nurses / attendants (one inside and one outside), and two technicians. There must be provision for the inside attendant to maintain hydration, including privacy for toileting. A lone inside attendant must hold the O_2 mask during O_2-breathing phases of the decompression. Inside attendants must not fly or be compressed again for at least 24 hours after completion of the treatment. Nor should they undertake strenuous exercise for at least 12 hours.

The workshop recommends recompression facilities in Australia and New Zealand should maintain a prospective database including all occasions when deep tables are used. The data set should include the indication for treatment, details of the conduct of the treatment including staffing and pressure profiles, any adverse effects on patients or staff, the number and nature of follow-up recompressions and the clinical outcome. Such information will be useful in further defining appropriate recompression schedule selection in the future. Consideration should be given to the development of an agreed deep recompression schedule, including recommended staffing levels, gas switching procedures, safety procedures and abort schedules.

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Acknowledgements: The authors would like to thank the HTNA for allowing us to conduct this workshop in conjunction with their 2011 Annual Scientific Meeting. We are grateful to all the attendees at the workshop for their enthusiastic participation and the contribution of their remarks to the final product.

Submitted: 15 April 2012
Accepted: 16 July 2012

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Editor's note:

Because of the considerable additional expense of reproducing a large number of colour images in the Journal, the several treatment tables discussed at the Workshop are gathered together on the Journal and Society websites in a pdf file entitled: *Treatment tables for the Deep Tables Workshop*. This may be found in the journal sections on the EUBS and SPUMS websites and in the featured article on the Journal website.

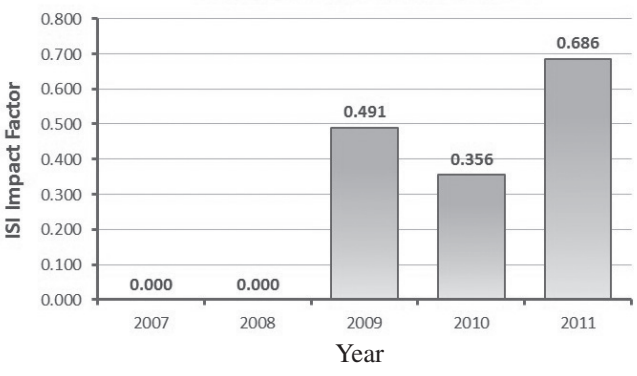
Diving and Hyperbaric Medicine – 5-year Impact Factor

Diving and Hyperbaric Medicine has now been indexed on the Thomson-Reuters database SciSearch® for five years. The five-year Impact Factor is shown in Figure 1. Note that no IF is given until after the first two years of indexation, so 2009 was the first year in which an IF was calculated.

Much of the level of the IF is the result of self-citation (that is, articles in DHM referring to other articles within the same journal). However, with back-indexing of the years 2008–2010 on PubMed, one would expect to see a further rise in the journal's IF over the next few years.

As the IF of a publication is generally regarded as a proxy for its relative importance within its field, the message is clear - please support your Journal!

Figure 1
Impact Factors for *Diving and Hyperbaric Medicine*



Continuing professional development

CME activity 2012/3

Chronic disease of professional divers

Jurg Wendling

Accreditation statement

Intended audience

The intended audience consists of all physicians subscribing to *Diving and Hyperbaric Medicine* (DHM), including anaesthetists and other specialists, who are members of the Australia and New Zealand College of Anaesthetists (ANZCA) Diving and Hyperbaric Medicine Special Interest Group (DHM SIG). However, all subscribers to DHM may apply to their respective CPD programme coordinator or specialty college for approval of participation. This activity, published in association with DHM, is accredited by the ANZCA Continuing Professional Development Programme for members of the ANZCA DHM SIG under Learning Projects: Category 2 / Level 2: 2 credits per hour.

Objectives

The questions are designed to affirm the participant's knowledge of the topics covered, and participants should be able to evaluate the appropriateness of the clinical information as it applies to the provision of patient care.

Faculty disclosure

Authors of these activities are required to disclose activities and relationships that, if known to others, might be viewed as a conflict of interest. Any such author disclosures will be published with each relevant CPD activity.

Do I have to pay?

All activities are free to subscribers.

Background reading

Practitioners are referred to the following background references and reading.

1 Edmonds C, Lourey G, Pennefather J, Walker R. *Diving and subaquatic medicine*, 4th edition, London: Hodder Arnold; 2002. Chapters 14 and 44.

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How to answer the questions

Please answer all responses (A to E) as True or False.

Answers should be posted by e-mail to the nominated CPD coordinator.

For EUBS members for this CPD issue this will be Jurg Wendling. ***E-mail:*** *<mail@wendling.ch>*

For ANZCA DHM SIG members, this will be David Cooper. ***E-mail:*** *<david.cooper@dhhs.tas.gov.au>*

On submission of your answers, you will receive a set of correct answers with a brief explanation of why each response is correct or incorrect. A correct response rate of 80% or more is required to successfully complete this activity. Each task will expire within 24 months of its publication to ensure that additional, more recent data have not superceded the activity.

Key words

MOPS (maintenance of Professional Standards), medical conditions and problems, occupational health, diving, dysbaric osteonecrosis, central nervous system, health surveillance

Question 1. With regard to signs of cerebral abnormalities after prolonged deep diving:

A. They have been shown to be related to a history of decompression sickness (DCS).

B. There is no evidence of diving-induced such signs in healthy occupational divers with long activity under appropriate safety management.

C. So-called grey and white matter lesions on MRI screening can be associated with a patent foramen ovale (with high degree shunting) in healthy divers who have experienced DCI.

D. They can be a reason for claiming disability compensation in a national health conservation programme.

E. The sharpened Romberg test combined with a specific symptoms check in the history will generally identify cerebral long-term health effects (LTHE).

Question 2. Dysbaric osteonecrosis (DON):

A. Was first observed in the 1930s when heliox diving was introduced.

B. Is typically diagnosed when bone damage is already established.

C. Can be easily proven these days by performing an MRI in doubtful cases, especially after pain-only DCS.

D. Is difficult to distinguish from idiopathic femoral head necrosis.

E. The incidence is very low for sports divers (with no decompression need); however, a rate of 0.5–60% has been reported for older professional divers or caisson workers, especially in the past.

Question 3. LTHE of diving as defined at the Consensus Conference in Norway 1993 are:

A. Chronic dysbaric disorders.

B. Sequelae of acute DCI.

C. Have insidious onset.

D. Not found in professional divers but typically in recreational deep divers.

E. Include neurosensory impairment due to noise and welding gas exposures.

Question 4. With regard to DON lesions:

A. Diagnostic investigations for possible DON after major bends DCI may consist of X-ray or MRI in the acute phase (as baseline only), and follow-up examinations not earlier than 6 months thereafter. Early MRI lesions may spontaneously disappear as they represent functional states while X-Ray lesions may appear much later.

B. Will need early surgical intervention in order to avoid progression of the disease.

C. X-ray changes represent zones of bone infarction by occlusion of small vessels. The theory says that these vessels are damaged directly or indirectly by microbubbles from inadequate decompression after hyperbaric exposure.

D. Morphologically two types are distinguished: juxta articular and shaft lesions. Shaft lesions tend to collapse and produce pain symptoms, while the juxta articular ones usually remain asymptomatic.

E. Divers with more than 20 h per week under pressure and going deeper than 30 msw should periodically be screened for DON. Traditionally, this means X-rays of the shoulders, hips and knees. A modern approach would be to perform MRI instead, as this avoids radiation exposure and is more sensitive.

Question 5. The medical examiner of divers should:

A. Perform a SPECT-tomography when suspecting a DON. With this technique, DON can best be distinguished from similar lesions caused by other aetiologies.

B. Propose a bone screening programme to the employer for divers being exposed to decompression stress known to be related to higher rates of DON.

C. Declare a diver with a DON type B (shaft lesion) unfit for diving.

D. Establish longitudinal neurological screening for those exposed to unusual decompression stress and environmental hazards (oil, gas, contaminants, dusts, etc).

E. Search for alcoholism and hyperlipidaemia when faced with an X-ray suggesting a DON.

Letters to the Editor

Ultrasound under pressure

Dear Editor,

I enjoyed the review article "*Ultrasound in diving and hyperbaric medicine*".[1] Gawthrope correctly asserts that ultrasound (US) is an excellent method to detect pneumothorax, pleural effusion, and adequacy of vascular filling, and that these skills are easily learnt. He also mentions more advanced uses of US in the hyperbaric chamber – intravascular bubble detection and cardiac function. The hyperbaric chamber is a potentially hostile environment in the sense that some of the usual clinical aids are often unavailable, and deterioration of the patient may produce a quandary as to whether the treatment session requires early cessation. I would like to mention other potential uses suitable for the hyperbaric environment.

US accurately confirms safe placement of endotracheal tubes – the tube can be visualized within the trachea and bilateral lung sliding shows both main bronchi are being ventilated.[2–4]

If there is clinical concern for raised intracranial pressure, US measurement of optic nerve sheath diameter may provide good guidance as to the need for urgent CT and/or neurosurgical intervention. A measurement greater than 5 mm is considered positive for intracranial hypertension.[5,6]

US can be very useful to assist in obtaining both peripheral and central venous access in the unwell patient. If central venous access has been obtained and the patient deteriorates subsequently, US can be used to exclude pneumothorax, haemothorax and cardiac tamponade.

I believe US is an important tool for use both prior to hyperbaric treatment and also within the course of hyperbaric treatment for critically ill patients. Many machines that are relatively inexpensive, easy to use and robust are available, but not all may be suitable or safe in a hyperbaric environment, and so each model must be carefully assessed prior to use.

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Key words
Ultrasound, hyperbaric medicine, equipment, letters (to the Editor)

Control groups in hyperbaric trials

Dear Editor,

I read with interest Dr Bennett's excellent recent appraisal of the study by Londahl and colleagues.[1–4] However, there are some concerns with respect to the trial design that I would like to highlight. Londahl et al's study on the addition of hyperbaric oxygen to specialised wound care for chronic diabetic foot ulcers uses a questionable "sham" treatment method, which has been employed by the same research team previously.[5] The paper by Londahl et al was also included in the recently updated Cochrane review of hyperbaric oxygen therapy for chronic wounds and appraised as having a low risk of bias, exclusively owing to the inclusion of a control group.[6]

What has not been commented on is whether their choice of control (sham) was appropriate. Londahl et al compared the effect of hyperbaric oxygen at 254 kPa in patients with diabetic foot ulcers with a sham group where patients breathed air at 254 kPa. In real terms, therefore, sham was equivalent to breathing 50% O_2 under normobaric conditions, which is not a true control. It could be argued that breathing 100% O_2 at normobaric pressure may have produced the same differences between the two groups. To better discern the effects of hyperbaric oxygen at 254 kPa a better control group would have been air at 1.0 ATA. Such an approach would confirm beyond doubt that the wound-healing effects are entirely attributable to hyperbaric oxygen.

There is also lack of discussion regarding the possible risk of decompression illness (DCI) in the control group since they are exposed to 90 mins of air at 254 kPa. This also raises ethical issues as the 'control' group is being exposed to a risk that the experimental group is not subject to. There were no reports of any adverse effects in the control arm, but the study only analysed 90 patients and the relative risk may be low, but still real. Conducting research in hyperbaric medicine is very difficult because of the problems of delivering sham treatments and Londahl and colleagues have improved substantially on previous published studies. For instance, the study by Annane et al gave hypoxic gas mixtures under pressure to their control group to ensure they received the same oxygen dose equivalent to a patient breathing air at normobaric pressure.[7] This was confirmed by blood gas analysis and the control group was therefore not only exposed to a potentially lethal gas mixture if pressurisation failed, but also the dual risks of arterial puncture and decompression sickness.

In order to undertake well-designed RCTs in hyperbaric medicine there has to be careful thought given to the appropriate control treatment group/sham, which should carry with it a negligible risk. Hyperbaric research needs to be promoted internationally and intervention trials should be designed with high methodological rigour. I disagree with Dr Bennett's assertion that this trial satisfied that principle.

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Key words
Hyperbaric oxygen therapy, wounds, diabetes, risk, ethics, letters (to the Editor)

EUBS European Underwater and Baromedical Society

Executive Committee (as of August 2012)

REUNION 2013

TRICONTINENTAL SCIENTIFIC MEETING ON DIVING AND HYPERBARIC MEDICINE

21–30 September

The European Underwater and Baromedical Society, the South Pacific Underwater Medicine Society and the Southern African Undersea and Hyperbaric Medical Association, in association with the Scott Haldane Foundation and the Association Réunionnaise de Médecine Subaquatique et Hyperbare are proud to announce their first ever, joint, tri-continental Annual Scientific Meeting.

We invite you to attend a full week of science, scuba and social interaction on the exotic French island of Réunion. Réunion lies 500 miles east of Madagascar, close to Mauritius, in the Indian Ocean. The conference will be hosted in the picturesque coastal village of St Gilles les Bains, where a range of hotel packages will be made available to suit all styles and budgets.

The meeting format will be a meld from all three societies, designed to satisfy the needs of all. The bulk of the academic content will be presented from Monday 23 September through Friday 27 September. To cater for variable flight availability, pre- and post-conference workshops and diving packages will be offered.

A call for abstracts and free papers will be made at a later date. The Organising Committee intends to publish all accepted abstracts as conference proceedings and will encourage all speakers to submit full papers for consideration in *Diving and Hyperbaric Medicine*.

Further information will be available on the website: <www.reunion2013.org>
All enquiries can be directed to: <info@reunion2013.org>

Please send us an e-mail if you think you will be attending.
This will help us greatly with planning logistics for this unprecedented event.

In anticipation and with many thanks from the Organising Committee:

Cyril d'Andrea, Unité fonctionelle de médecine hyperbare La Réunion
Peter Germonpré, President EUBS
Karen Richardson, Secretary SPUMS
Jonathan Rosenthal, President SAUHMA
Jan-Jaap Brandt Corstius, Director Scott Haldane Foundation

EUBS

SPUMS

SOUTHERN AFRICAN UNDERSEA AND HYPERBARIC MEDICAL ASSOCIATION

Scott Haldane Diving Medicine

SPUMS notices and news

South Pacific Underwater Medicine Society Diploma of Diving and Hyperbaric Medicine

Requirements for candidates (updated October 2008)

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 medically qualified, and be a current financial member of the Society.
2 The candidate must supply evidence of satisfactory completion of an examined two-week full-time course in Diving and Hyperbaric Medicine at an approved facility. The list of approved facilities providing two-week courses may be found on the SPUMS website.
3 The candidate must have completed the equivalent (as determined by the Education Officer) of at least six months' full-time clinical training in an approved Hyperbaric Medicine Unit.
4 The candidate must submit a written proposal for research in a relevant area of underwater or hyperbaric medicine, in a standard format, for approval *before* commencing their research project.
5 The candidate must produce, to the satisfaction of the Academic Board, a written report on the approved research project, in the form of a scientific paper suitable for publication. Accompanying this written report should be a request to be considered for the SPUMS Diploma and supporting documentation for 1–4 above.
6 In the absence of documentation otherwise, it will be assumed that the paper is submitted for publication in *Diving and Hyperbaric Medicine*. As such, the structure of the paper needs to broadly comply with the 'Instructions to Authors' – full version, published in *Diving and Hyperbaric Medicine* 2010; 40(2):110-2.
7 The paper may be submitted to journals other than *Diving and Hyperbaric Medicine*; however, even if published in another journal, the completed paper must be submitted to the Education Officer for assessment as a diploma paper. If the paper has been accepted for publication or published in another journal, then evidence of this should be provided.
8 The diploma paper will be assessed, and changes may be requested, before it is regarded to be of the standard required for award of the Diploma. Once completed to the reviewers' satisfaction, papers not already submitted to, or accepted by other journals should be forwarded to the Editor of *Diving and Hyperbaric Medicine* for consideration. At this point the Diploma will be awarded, provided all other requirements are satisfied. Diploma projects submitted to *Diving and Hyperbaric Medicine* for consideration of publication will be subject to the Journal's own peer review process.

Additional information – prospective approval of projects is required

The candidate must contact the Education Officer in writing (e-mail is acceptable) to advise of their intended candidacy, and to discuss the proposed subject matter of their research. A written research proposal must be submitted before commencing the research project.

All research reports must clearly test a hypothesis. Original basic or clinical research is acceptable. 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 NHMRC/AVCC statement and guidelines on research practice (available at: <http://www.health.gov.au/nhmrc/research/general/nhmrcavc.htm>) or the equivalent requirement of the country in which the research is conducted. All research involving humans or animals must be accompanied by documented evidence of approval by an appropriate research ethics committee. It is expected that the research project and the written report will be primarily the work of the candidate, and that the candidate is the first author, where there are more than one.

The SPUMS Diploma will not be awarded until all requirements are completed. The individual components do not necessarily need to be completed in the order outlined above. However, it is mandatory that the research project is approved prior to commencing research.

The Academic Board reserves the right to modify any of these requirements from time to time. As of October 2011, the SPUMS Academic Board consists of:
Associate Professor David Smart, Education Officer;
Associate Professor Simon Mitchell;
Associate Professor (retired) Mike Davis.

All enquiries and applications should be sent to the Education Officer:
Associate Professor David Smart
GPO Box 463, Hobart, Tasmania 7001
E-mail: *<david.smart@dhhs.tas.gov.au>*

Key words
Qualifications, underwater medicine, hyperbaric oxygen, research, medical society

Minutes for the Annual General Meeting of SPUMS at Madang Resort, Madang, Papua New Guinea, 24 May 2012

Opened: 1642 h

Present
The President, M Bennett and 33 voting members

Apologies
G Hawkins, G Williams, D Smart, J Lehm, C Acott, A Fock
Apologies from the floor: I Gawthrop, made by N Banham

1. Minutes of the 2011 AGM
Minutes of the previous annual general meeting were published in *Diving Hyperb Med*. 2011;41(3):170-5 and posted in the conference venue.
Motion that the minutes be accepted as an accurate record proposed K Richardson, seconded D Wilkinson, carried

2. Matters arising from previous minutes
Nil

3.(i) President's report: M Bennett
Report published in the Presidents' pages in this issue.
Comments from floor: N Brennan proposes to increase SPUMS awareness via free advertising on the Internet by placing the SPUMS logo and website link on the "*Whatsthatfish*" website. This is a free-access website run by two society members, which receives around 700 hits per day. Use of the SPUMS link will increase our ranking on Internet search engines. M Bennett notes this is a not-for-profit hobby site useful to our membership, hence there are no commercial conflicts.
Motion to reciprocate website links proposed M Davis, seconded C Meehan, carried

3.(ii) Secretary's report: K Richardson
Comments from floor: none
Motion to accept Secretary's report proposed by C Meehan, seconded N Banham, carried

3.(iii) Education Officer's report: D Smart (presented by M Bennett)
Comments from the floor: M Ignatescu notes she has completed the Stellenbosch course and highly recommends this programme. Recognition of prior learning enabled her to be credited for one subject.
Motion to accept Education Officer's report proposed K Richardson, seconded by C Meehan, carried

3.(iv) ANZHMG Representative's report: D Smart (presented by M Bennett)
Report published in *Diving Hyperb Med*. 2012;42:116-7.
Comments from the floor: M Bennett notes that MSAC accepted radiation treatment but rejected non-diabetic chronic wounds. The report that was submitted was not that prepared by the advisory committee, hence DS and MB submitted a dissenting report and this has not been acknowledged. Several avenues will be pursued to challenge the outcome.
Motion to accept ANZHMG Representative's report proposed J Hissink, seconded N Banham, carried

3.(v) Treasurer's report: J Lehm (presented by K Richardson)
Comments from the floor (incorporating Annual Financial Statement): C Meehan questions the donation item, M Bennett will enquire to Treasurer re same; S Bowen notes that confusion re retrospective costs to ASM could be resolved by having separate line items for each year's ASM; C Meehan questions overall cost of 2011 ASM; S Lockley replies approximately AUD55,000 with around AUD3,500 profit; M Bennett notes meetings are budgeted to break even with relatively low attendance, hence we sometimes make a small profit; M Davis notes this money is often used to seed the next year's ASM.
Motions to accept Treasurer's report, Annual Financial Statement and appoint Mediq Financial Services as auditor for the coming financial year proposed by M Davis, seconded J Hissink, carried

3.(vi) Journal Editor's Report: M Davis
Comments from floor: none
Motion to accept Editor's report proposed M Bennett, seconded M Ignatescu, carried

4. Committee Performance Indicator reports
KPI: Attendance at Committee Meetings, minimum 4 of 6
Comments: C Acott has not attended a SPUMS Executive Committee (ExCom) meeting in over 18 months; apologies received from A Fock and C Acott for November 2011 face-to-face meeting, apologies from C Acott and M Davis for April 2012 teleconference. Failure to make Quorum at May 2012 Committee Meeting noted with apologies from C Acott, A Fock, J Lehm, P Smith, D Smart, G Williams and G Hawkins.
KPI: Minuted actions addressed within a timeframe determined at the meeting.
Comments: variable response from committee members; copy of unedited minutes showing failures with regard to this KPI available on application to the Secretary.
KPI: Webmaster addresses requests for change to website in a timely fashion.
Comments: Changes to the website have taken multiple requests to achieve and a number of issues are unresolved, KPI not achieved.
KPI: Secretary circulates 90% of minutes in draft form within 4 weeks of Excom meetings.
Minutes for the 2011 AGM and November 2011 face-to-face meeting received promptly. Minutes for the April teleconference submitted 5 weeks after the event. KPI achieved.
KPI: Public Officer lodges all documents with authorities before due date.
Comments: KPI satisfied.

KPI: Education Officer ensures all SPUMS diplomas are awarded and notified to Excom and DHM.
Comments: KPI satisfied to the best of our knowledge; N Banham notes he completed his diploma in November 2011 and this may not have been notified.
KPI: Treasurer ensures counter-signing payments occurs in a timely fashion.
Comments: difficulties with the St George Bank noted. This has been achieved with the kind assistance of S Lockley, G Williams and P Smith.

5. Annual Financial Statement: Dr J Lehm (presented by M Bennett)

6. Subscription fees for 2013
The Treasurer recommends that the annual fees remain unchanged for 2013. Full membership fee is AUD175 if paid on-line before January 31st and AUD200 if paid later. Paper renewals are an extra AUD10 and shipping DHM to an address outside NZ/Australia will add a further AUD10. Corporate membership fee is AUD440.
Motion to retain fees at current level, proposed N Brennan, seconded C Gibbs, carried unanimously

7. Election of Office Bearers
One nomination was received for the position of Executive Committee Member.
Nominee: Denise Blake (elected unopposed)
Resignation from the SPUMS committee has been received from G Hawkins, who will retain his appointed position as Webmaster. Associate Professor Simon Mitchell has been co-opted to hold the vacated Executive Committee member position until a formal election is held at AGM 2013.
No nominations have been received for the position of Treasurer prior to the AGM. A call was made for nominations from the floor. M Ignatescu nominated Shirley Bowen, seconded C Meehan and supported by widespread acclaim. S Bowen accepted the nomination and was elected to the position of Treasurer unopposed.

In accordance with the above elections, S Bowen and D Blake will become signatories and authorised users of Business Banking On-Line for the SPUMS St George accounts. Furthermore, the new Treasurer, S Bowen, will take over the SPUMS Visa card from the current Treasurer, J Lehm. G Williams, who has completed his term on the Executive Committee, will be removed from the list of authorised account users. The list of people authorised to operate the various SPUMS accounts is, therefore: Treasurer, Shirley Bowen; Public Officer, Andrew Fock; WebMaster, Glen Hawkins; Committee Member, Peter Smith; Committee Member, Denise Blake.

8. Appointment of the auditor and book-keeper 2012
Barrett, Baxter and Bye informed the Treasurer that owing to new regulations and lack of qualified staff they were unable to perform the annual audit. Mediq Financial Services prepared a certified audit of the accounts at very short notice. J Lehm recommends that, in future, we do not require an official company auditor to prepare a forensic audit at high cost, but rather we use a CPA-accredited accountant to prepare an independent audit. J Lehm recommends the company Mediq Financial Services.

Comments from the floor: M Bennett notes changes in the Australian legislation such that a full company audit requires a highly specialized person at the cost of several thousand dollars and that BBB can no longer provide this service; many small businesses have audits done by CPA auditors; M Bennett and J Lehm do not believe SPUMS needs a full forensic audit every year. M Davis notes that the Society is registered in Victoria and questions if there was an advantage to a Melbourne-based services;, none were identified.

The Committee has been unable to formally discuss the recommendation to employ a book-keeper for the Society in order to reduce the workload of the Treasurer. Three quotes have been received for the combined services of accountant, book-keeper and auditor and the Committee will consider these and make a recommendation to the Society in the near future.

N Brennan asks if these issues should be put to full membership or decided by the Committee. M Bennett responds it may be inappropriate to vote on this now as the Committee has not had an opportunity to discuss this issue. C Meehan notes that the Treasurer should not recommend this as he may himself need auditing. M Bennett responds that auditing is a self-imposed rule adopted subsequent to trouble with a previous Treasurer.
Proposal made by M Bennett: The Committee be allowed to discuss this issue then put the vote to Society membership via e-mail as per the new constitutional changes.

9. Business of which notice has been given:
None

Closed: 1744 h

Important notice:

The detailed annual reports from Officers of the Society and the financial statement for 2011 are now presented in the members-only section on the SPUMS website: <www.spums.org.au>. The PDF file is entitled:
"*SPUMS AGM 24 May 2012 Reports*".

Key words
Medical society, meetings

Minutes of the Executive Committee Meeting of SPUMS at Madang Resort, Madang, Papua New Guinea, 20 May 2012

Opened: 1500 h

Present: M Bennett, M Davis and K Richardson

Apologies: G Hawkins, G Williams, D Smart, J Lehm, C Acott, A Fock, P Smith

As the minimum number of Executive Committee members required to make quorum is four, the meeting could not be held and was adjourned, to lapse.

Closed: 1530 h

Key words
Medical society, meetings

Education Officer's Report, July 2012

SPUMS Diplomas: No Diplomas were awarded in the April–June quarter, 2012; however, it is encouraging that there are three projects that have been submitted and reviewed and are very close to completion. A further four candidates have registered and had their projects approved. There has been increasing interest in the Diploma, which is very pleasing.

Diving Medicine Courses: No news to report.

Associate Professor David Smart
Medical Co-director, Department of Diving and Hyperbaric Medicine
Royal Hobart Hospital
GPO Box 463
Hobart, Tasmania
E-mail: *< david.smart@dhhs.tas.gov.au>*

Key words
Qualifications, medical society, underwater medicine, hyperbaric oxygen, research

ANZCA Certificate in Diving and Hyperbaric Medicine

Eligible candidates are invited to present for the examination for the Certificate in Diving and Hyperbaric Medicine of the Australian and New Zealand College of Anaesthetists.

Eligibility criteria are:

1 Fellowship of a Specialist College in Australia or New Zealand. This includes all specialties, and the Royal Australian College of General Practitioners.

2 Completion of training courses in Diving Medicine and in Hyperbaric Medicine of at least four weeks' total duration. For example, one of:
   a ANZHMG course at Prince of Wales Hospital Sydney, **and** Royal Adelaide Hospital or HMAS Penguin diving medical officers course **OR**
   b Auckland University Diploma in Diving and Hyperbaric Medicine.

3 **EITHER:**
   a Completion of the Diploma of the South Pacific Underwater Medicine Society, including six months' full-time equivalent experience in a hyperbaric unit and successful completion of a thesis or research project approved by the Assessor, SPUMS
   b **and** Completion of a further 12 months' full-time equivalent clinical experience in a hospital-based hyperbaric unit which is approved for training in Diving and Hyperbaric Medicine by the ANZCA.

   OR:
   c Completion of 18 months' full-time equivalent experience in a hospital-based hyperbaric unit which is approved for training in Diving and Hyperbaric Medicine by the ANZCA
   d **and** Completion of a formal project in accordance with ANZCA Professional Document TE11 "Formal Project Guidelines". The formal project must be constructed around a topic which is relevant to the practice of Diving and Hyperbaric Medicine, and must be approved by the ANZCA Assessor prior to commencement.

4 Completion of a workbook documenting the details of clinical exposure attained during the training period.

5 Candidates who do not hold an Australian or New Zealand specialist qualification in Anaesthesia, Intensive Care or Emergency Medicine are required to demonstrate airway skills competency as specified by ANZCA in the document "*Airway skills requirement for training in Diving and Hyperbaric Medicine*".

All details are available on the ANZCA website at:
<www.anzca.edu.au/edutraining/DHM/index.htm>

Dr Suzy Szekely, FANZCA
Chair, ANZCA/ASA Special Interest Group in Diving and Hyperbaric Medicine, Australia
E-mail: *<Suzy.Szekely@health.sa.gov.au>*

A Specialist in Anaesthesia with interest in Hyperbaric Medicine is required at London Hyperbaric Medicine as soon as possible

This part-time position will be shared with three other consultant anaesthetists and is therefore easily compatible with a job abroad. The commitment is one week per month and can be arranged in blocks.

London Hyperbaric Medicine operates the only hyperbaric unit in the Greater London Area with a 24 h emergency service. It is located on campus of Whipps Cross University Hospital in North-East London. We treat the full spectrum of indications by international standards of hyperbaric medicine, including decompression illness, carbon monoxide poisoning, problem wounds, bone and tissue radionecrosis and necrotizing fasciitis. We are in the early stages of implementing a full anaesthetic cover for critically ill patients requiring treatment in the hyperbaric chamber.

Applicants must be eligible for inclusion on the GMC's Specialist Register. They should have experience in the treatment of intubated patients in a hyperbaric chamber. Furthermore, knowledge in diving medicine is desirable.

The successful candidate will join a highly motivated, international team of eight hyperbaric physicians, 16 nurses and 10 chamber technicians. (S)he will be required to work blocks of an average of seven days per month. Regular working hours are weekdays from 9 am to 5 pm. The on-call commitment is one week night and one weekend per month. Outside these periods, the applicant may be involved only in cases of critically ill patients.

This job opportunity offers an attractive salary at consultant level in Pound Sterling, with additional remuneration for the treatment of intensive care patients. Free-of-charge accommodation is provided in an apartment close to the workplace in Leytonstone. The city centre is easily accessible in 20 minutes via public transport (Central Line directly to Oxford Circus). Stansted Airport can be reached in 30 minutes and offers convenient connections to most European destinations.

Please send your application to:
Dr Pieter Bothma, Medical Director, London Hyperbaric Medicine, Whipps Cross Road, London E11 1RG.

Royal Adelaide Hospital
Hyperbaric Medicine Unit Courses 2012

Medical Officers' Course *December 2012*
Unit 1 03–07 December
Unit 2 10–14 December
For further information, please contact:
E-mail: <Lorna.Mirabelli@health.sa.gov.au >
Phone: +61-(0)8-8222-5116

Advertising in *Diving and Hyperbaric Medicine*

Commercial advertising is now welcomed within the pages of *Diving and Hyperbaric Medicine*. Companies and organisations within the diving, hyperbaric medicine and wound-care communities who might wish to advertise their equipment and services are welcome. The advertising policy of the parent societies – EUBS and SPUMS – appears on the journal website: <www.dhmjournal.com>.

Details of advertising rates and formatting requirements are available on request from:
E-mail: <editor@dhmjournal.com>
Fax: +64-(0)3-329-6810

Royal Australian Navy Medical Officers' Underwater Medicine Course 2012

Dates: 05–16 November 2012
Venue: HMAS PENGUIN, Sydney

The MOUM course seeks to provide the medical practitioner with an understanding of the range of potential medical problems faced by divers. Considerable emphasis is placed on the contra-indications to diving and the diving medical, together with the pathophysiology, diagnosis and management of the more common diving-related illnesses. The course includes scenario-based simulation focusing on management of diving emergencies and workshops covering the key components of the diving medical.

Cost: AUD705 without accommodation
(AUD2,100 with accommodation at HMAS Penguin)

For information and application forms contact:
Rajeev Karekar, for Officer in Charge,
Submarine and Underwater Medicine Unit
HMAS PENGUIN
Middle Head Rd, Mosman
NSW 2088, Australia
Phone: +61-(0)2-9647 5572
Fax: +61-(0)2-9960 4435
E-mail: <Rajeev.Karekar@defence.gov.au>

DIVING HISTORICAL SOCIETY AUSTRALIA, SE ASIA

P O Box 347, Dingley Village
Victoria, 3172, Australia
E-mail:
<deswill@dingley.net>
Website:
<www.classicdiver.org>

Scott Haldane Foundation

The Scott Haldane Foundation is dedicated to education in diving medicine, and has organised more than 100 courses over the past few years, both in the Netherlands and abroad. Below is a list of courses planned for the remainder of 2012. More information can be found at: <www.scotthaldane.nl>.

The new basic course (Part I plus Part II) fully complies with the current EDTC/ECHM curriculum for Level I (Diving Medical Examiner), and the different advanced courses offer a modular way to achieve Level IIa competence according to the EDTC/ECHM guidelines.

Course details for second half of 2012

19–20 October In-depth Course "*Diving accidents*" (Driebergen, The Netherlands)
09–17 November: Basic Course Part I (Maldives)
16–24 November: 20th In-depth Course "*Challenges in diving medicine*" (Maldives)
23 November–01 December: 20th In-depth Course "*Challenges in diving medicine*" (Maldives)

For further information: <www.scotthaldane.nl>

British Hyperbaric Association Annual Scientific Meeting 2012

Dates: 09–11 November 2012

Venue: Sheraton Skyline Hotel, Heathrow Airport, UK

This is a Joint BHA meeting with the Association of Aviation Medical Examiners
Meeting theme: Medicine in extreme environments
More details will be available soon.
Website: <http://www.hyperbaric.org.uk>

EUBS ASM 2014

Preliminary notice

Dates: 24–27 September 2014
Venue: Wiesbaden

The German Society for Diving and Hyperbaric Medicine (GTUeM) has appointed Dr Peter Müller to serve as the Secretary General for the EUBS ASM 2014. This will be held in conjunction with the 2014 congress of GTUeM.

For further information at this early stage contact:
E-mail: <peter.mueller@eubs.org>

Hyperbaric Oxygen, Karolinska

Welcome to: <http://www.hyperbaricoxygen.se/>. This site, supported by the Karolinska University Hospital, Stockholm, Sweden, offers publications and free, high-quality video lectures from leading authorities and principal investigators in the field of hyperbaric medicine.

You need to register to obtain a password via e-mail. Once registered, watch the lectures on-line, or download them to your iPhone or computer for later viewing.

We offer video lectures from:
- The 5th Karolinska PG course in clinical hyperbaric oxygen therapy, 07 May 2009
- The European Committee for Hyperbaric Medicine '*Oxygen and infection'* Conference, 08–09 May 2009
- The 17th International Congress on Hyperbaric Medicine, Cape Town, 17–18 March 2011

Also available is the 2011 Stockholm County Council report: *Treatment with hyperbaric oxygen (HBO) at the Karolinska University Hospital*

For further information contact:
Folke Lind, MD, PhD
E-mail: <folke.lind@karolinska.se>
Website: Editor <www.hyperbaricoxygen.se>

German Society for Diving and Hyperbaric Medicine (GTUeM)

An overview of basic and refresher courses in diving and hyperbaric medicine, accredited by the German Society for Diving and Hyperbaric Medicine (GTUeM) according to EDTC/ECHM curricula, can be found on the website: <http://www.gtuem.org/212/Kurse_/_Termine/Kurse.html>

Undersea and Hyperbaric Medical Society 46th Annual Scientific Meeting

Dates: 13–15 June 2013
Venue: Lowes Royal Pacific Resort @ Universal Studios Orlando, Florida, USA
Phone: +1-(0)877-533-UHMS (8467)
E-mail: <lisa@uhms.org>
Website: <www.uhms.org>

Inter-university Diploma in Diving and Hyperbaric Medicine, France

For further information go to:
<http://www.medsubhyp.org> or
<http://medecine.univ-lille2.fr/format/diu/hyperbar.htm>

Instructions to authors

(Short version, updated December 2011)

Diving and Hyperbaric Medicine welcomes contributions (including letters to the Editor) on all aspects of diving and hyperbaric medicine. Manuscripts must be offered exclusively to *Diving and Hyperbaric Medicine*, unless clearly authenticated copyright exemption accompanies the manuscript. All manuscripts will be subject to peer review. Accepted contributions will also be subject to editing. An accompanying letter signed by all authors should be sent.
Contributions should be sent to:
The Editor, Diving and Hyperbaric Medicine,
C/o Hyperbaric Medicine Unit, Christchurch Hospital,
Private Bag 4710, Christchurch, New Zealand.
E-mail: <editor@dhmjournal.com>

Requirements for manuscripts
Documents should be submitted electronically. The preferred format is Microsoft® Office Word or rich text format (RTF). Paper submissions will not be accepted. All articles should include a title page, giving the title of the paper and the full names and qualifications of the authors, and the positions they held when doing the work being reported. Identify one author as correspondent, with their full postal address, telephone and fax numbers, and e-mail address supplied. The text should generally be subdivided into the following sections: a structured Abstract of no more than 250 words, Introduction, Methods, Results, Discussion, Conclusion(s), Acknowledgements and References. Acknowledgements should be brief. Legends for tables and figures should appear at the end of the text file after the references. Conflicts of interest and funding sources should be identified.

The text should be 1.5 lines spaced, using both upper and lower case. Headings should conform to the current format in *Diving and Hyperbaric Medicine*. All pages should be numbered. Underlining should not be used. SI units are to be used (mmHg is acceptable for blood pressure measurements; bar for cylinder pressures); normal ranges should be shown. Abbreviations may be used after being shown in brackets after the complete expression, e.g., decompression illness (DCI) can thereafter be referred to as DCI.

Preferred length for **Original Articles** is up to 3,000 words. Inclusion of more than five authors requires justification, as does that of more than 30 references. **Case Reports** should not exceed 1,500 words, and a maximum of 15 references. Abstracts are required for all articles. **Letters to the Editor** should not exceed 500 words and a maximum of five references. Legends for figures and tables should generally be shorter than 40 words in length.

Illustrations, figures and tables must NOT be embedded in the wordprocessor document, only their position indicated, and each should be submitted as a separate file.
Tables should be presented either with tab-separated columns (preferred) or in table format. No gridlines, borders or shading are to be used.
Illustrations and figures should be submitted in TIFF, high resolution JPG or BMP format. If figures are created in Excel, submit the complete Excel file. Large files (>10 Mb) should be submitted on disk.
Photographs should be glossy, black-and-white or colour. Colour printing is available only when it is essential and will be at the authors' expense. Indicate magnification for photomicrographs.

References
The Journal reference style is based closely on the the *International Committee of Medical Journal Editors (ICMJE) Uniform Requirements for Manuscripts*. Examples are given in detail at:
<http://www.nlm.nih.gov/bsd/uniform_requirements.html> (last updated August 2009). References must appear in the text as superscript numbers at the end of the sentence after the full stop.[1,2] Numbered them in order of quoting. Use Index Medicus abbreviations for journal names:
<http://www.nlm.nih.gov/tsd/serials/lji.html>
Examples of the exact format for a standard paper and a book are given below:

1 Freeman P, Edmonds C. Inner ear barotrauma. *Arch Otolaryngol*. 1972;95:556-63.
2 Hunter SE, Farmer JC. Ear and sinus problems in diving. In: Bove AA, editor. *Bove and Davis' diving medicine*, 4th ed. Philadelphia: Saunders; 2003. p. 431-59.

Accuracy of references is the responsibility of the authors.

Manuscripts not complying with the above requirements will be returned to the author(s) before being considered for publication.

Consent
Studies on human subjects must comply with the Helsinki Declaration of 1975 (revised 2000) and those using animals must comply with health and medical research council guidelines or their national equivalent. A statement affirming ethics committee (institutional review board) approval should be included in the text. A copy of that approval (and consent forms) should be available if requested.

Copyright
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Full instructions to authors (revised July 2011) may be found on the DHM Journal, EUBS and SPUMS websites and should be consulted before submission.

DIVER EMERGENCY SERVICES PHONE NUMBERS

AUSTRALIA
1800-088200 (in Australia, toll-free)
+61-8-8212-9242 (International)

NEW ZEALAND
0800-4DES-111 (in New Zealand, toll-free)
+64-9-445-8454 (International)

ASIA
+852-3611-7326 (China)
+10-4500-9113 (Korea)
+81-3-3812-4999 (Japan)

SOUTHERN AFRICA
0800-020111 (in South Africa, toll-free)
+27-10-209-8112 (International, call collect)

EUROPE
+39-6-4211-8685 (24-hour hotline)

UNITED KINGDOM
+44-7740-251-635

USA
+1-919-684-9111

The DES numbers (except UK) are generously supported by DAN

DAN Asia-Pacific DIVE ACCIDENT REPORTING PROJECT

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 regard to identifying details, is utilised in reports on fatal and non-fatal cases. Such reports can be used by interested people or organisations to increase diving safety through better awareness of critical factors.

Information may be sent (in confidence unless otherwise agreed) to:
DAN Research
Divers Alert Network Asia Pacific
PO Box 384, Ashburton VIC 3147, Australia
Enquiries to: <research@danasiapacific.org>

DAN Asia-Pacific NON-FATAL DIVING INCIDENTS REPORTING (NFDIR)

NFDIR is an ongoing study of diving incidents, formerly known as the Diving Incident Monitoring Study (DIMS). An incident is any error or occurrence which could, or did, reduce the safety margin for a diver on a particular dive. Please report anonymously any incident occurring in your dive party. Most incidents cause no harm but reporting them will give valuable information about which incidents are common and which tend to lead to diver injury. Using this information to alter diver behaviour will make diving safer.

The NFDIR reporting form can be accessed on line at the DAN AP website:
<www.danasiapacific.org/main/accident/nfdir.php>

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Diving and Hyperbaric Medicine is indexed on MEDLINE, SciSearch® and Embase/Scopus

Printed by Snap Printing, 166 Burwood Road, Hawthorn, Victoria 31222, <hawthorn@snapprinting.com.au>