The salvage of the *Wahine*: an exercise in occupational medicine

Anthony G Slark

Key words
Occupational diving, occupational health, decompression sickness, computers, safety, history

Abstract

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In 1968, the inter-island ferry *Wahine* sank in the entrance to Wellington Harbour in a wild storm with the loss of 51 lives. Following a further storm, attempts to refloat the vessel were abandoned. This report, written over 30 years ago by Tony Slark as the diving medical consultant to the salvage operation, describes some of the medical aspects involved in the cutting up and clearing of the wreck between 1968 and 1973. It includes two detailed case descriptions of decompression sickness. From April 1970, Dr Slark introduced the SOS decompression meter to control all diving operations, with over 10,800 hours of diving time being completed without any further incidents of decompression sickness.

Introduction

The inter-island ferry *Wahine* sank in Wellington Harbour in a wild storm in April 1968 with the loss of 51 lives. It was initially hoped that the salvage of the vessel could be performed by refloating the whole hull with foam and compressed air. However, a further storm in May 1969 shifted the vessel breaking it up to such a degree that the original concept of salvage had to be abandoned in favour of raising the individual broken sections. However, further deterioration of the hull occurred and eventually the system of salvage necessary has been the piecemeal cutting of the hulk into sections capable of being lifted from the bottom by the support vessel *Holm Park* anchored beside the wreck. This has required the formation of a team of professional divers working constantly on the wreck to cut it into manageable sections.

During the initial period when the wreck remained in one piece lying on the sea-bed, the diving work consisted primarily of the removal of vehicles and cargo, and the cutting down of the superstructure. Twelve divers were employed for a period of approximately 3,000 hours underwater. During this time there was no organised system of decompression, but no bends resulted. It can be assumed that much of the diving took place at depths less than necessary for the production of a sufficient degree of nitrogen supersaturation to make decompression sickness possible. The average working depth was in the region of 40–50 feet of sea water (fsw).

When work was begun after the wreck had broken up, the maximum working depth increased to 70 fsw. Again, no organised system of decompression was used. During this time two divers suffered attacks of decompression sickness. Four divers only constituted the team during this time, which extended from October 1969 to March 1970, and they put in about 1,400 hours of work underwater.

Case report one

On 2 March 1970, the senior diver of the team, a man aged 52 years, a professional of many years’ experience working underwater, surfaced about 4 pm after a total of 4 hours at 60 fsw. He did not perform any decompression time. The American Naval Tables would have suggested a total ascent time of some 82 minutes and the Royal Naval Tables [a] total decompression time of 90 minutes. Even with such a decompression time the tables are reckoned to have a possible 10% bends rate for such prolonged exposures.

The diver first noticed a pain in his left biceps, forearm and wrist with some pain in his left groin. The pain started some three hours after surfacing and he felt it became really unbearable in the early hours of the morning. He recognised that he was suffering from decompression sickness having had similar bouts before, and arrangements were made by the Salvage Master for him to be flown direct to Auckland first thing in the morning so that recompression could be offered him if necessary. He came by ordinary commercial flight which meant that he suffered further decompression stress during the flight for the cabin is only pressurised to an equivalent level of 5,000 ft. However, he did not remark upon any exacerbation of his symptoms.

On arrival he was able to walk into the consulting room and give a good account of the circumstances. He described his pain as being more severe than he had felt on any previous occasion, but did not admit to any neurological symptoms. His bladder function was normal. General medical examination revealed no abnormal signs, apart from brisk tendon reflexes throughout, and bilateral upgoing plantar responses. Since he described one major previous bend as having a considerable neurological content this finding was ascribed to the earlier incident, for which incidentally he had not received treatment with recompression.
He was asked whether he felt able to put up with the pain while a further medical examination took place – he said he would rather not. I would have wished to have done a chest X-ray, electrocardiogram and full blood screening, but he was quite blunt in his lack of enthusiasm for any delay. Since analgesia would have confused the decision-making process whilst under recompression treatment, I decided to recompress him forthwith. He was put under pressure at approximately 10.30 that morning and we tried initially the ‘minimal-pressure oxygen recompression’ schedule, which involved initial compression to a depth of 60 fsw on pure oxygen for 20 minutes with breaks in air after each 20 minutes for 5 minutes. This latter is designed to prevent oxygen poisoning. Towards the end of the first oxygen period it became obvious that he was receiving little benefit, and it was therefore decided to proceed with the longer air table. He was therefore compressed further to a level of 165 fsw on Table 5B of the Royal Naval Diving Manual. After a short spell at this depth he noted a very great relief in the pain and following this, decompression on the schedule proceeded uneventfully. He left the chamber at 10.30 that evening complaining only of a very slight tenderness of the left upper arm and with virtually no other abnormalities apart from the minor neurological signs noted previously. He was kept under observation at the Naval Hospital for the following day, during which time routine medical examinations were performed, including chest X-ray and electrocardiogram and blood screening. Apart from an ESR of 40 [sec] and a haemoglobin of 13 [g.100ml⁻¹] there were no abnormalities detected. He did not have a platelet examination or blood lipid screening as would now be my practice.

It was noted that he had a marked limp. And examination of his legs revealed shortening of the left leg of approximately three quarters of an inch. There were no symptoms relevant to this and he had what seemed a fairly full range of painless movement. It was decided to perform a full X-ray screening of him for the possibility of aseptic [bone] necrosis. This was confirmed by the X-rays, which showed a very widespread involvement with virtual complete destruction of his left hip and widespread necrosis throughout the long bones and many infarcts involving joint surfaces in other parts.

Because of this he was advised most strongly that in future his diving should be confined to supervision. It is interesting that his pattern of diving i.e., that of doing long periods at relatively shallow depths was similar to the pressure changes experienced by tunnel and caisson workers in whom aseptic [bone] necrosis is a far more common finding. He was, however, the sort of older worker who always wishes to show the younger generation that he can do more and do it better. He did not in fact follow my advice and continued his diving for a further fairly extensive period. The Salvage Master said he had had the limp for 15 years. He would often actively refuse to undergo decompression and cut it short if he could. Many of the old school divers regarded bends as some lack of courage. This attitude, of course, influenced the younger divers. I understand, however, that his arthritis has still not caused him much pain though he has now retired from diving completely.

Case report two

The following week another diver of the team, a man aged 25 years, was sent to us with similar symptoms. He had been diving at a depth of 65 feet for 3.5 hours without decompression. This exposure according to the Royal Naval Tables should have required a total decompression time of 115 minutes, and on the US Naval Tables for exceptional exposures a time of ascent of 179 minutes. He stated that 15 minutes after surfacing severe pain had begun in his left shoulder, a less severe pain in the left elbow and some slight numbness of the fingers of his left hand. There were no other significant signs on examination and the central nervous system seemed quite normal in all respects. He was accordingly recompressed again. Initially an attempt was made to treat him on the minimal-pressure oxygen table but with no relief. Once more we recompressed further on the much longer deep air table and he stated fairly soon after being at 165 ft [sw pressure]. that he had considerable relief of his symptoms. Decompression according to Table 5B continued uneventfully and he was removed from the chamber the next day complaining only of some slight ache in the left shoulder. Further examination was performed at the Naval Hospital including electrocardiogram, blood investigation and a full series of X-ray examinations. None of these revealed any significant abnormalities and he was therefore returned to Wellington and has since continued to dive, and is now their second in charge.

Management of diving operations from April 1970

It was obvious that with two cases occurring in such a short space of time, both illustrating a complete absence of proper precautions for decompression following prolonged time underwater, some review of the safety precautions offered the workers on the salvage operation was required.

It was obvious that the senior diver’s long personal apparent immunity to decompression sickness had allowed a rather casual approach to develop in the team, and I think that it was very much a matter of familiarity breeds contempt. The Salvage Master himself had faith in his chief diver with whom he had worked for many years, and had had no reason hitherto to concern himself much with the detail of the safety aspects of the diving side to the work. He also wished to avoid undermining his authority which he thought was precariously maintained. However, the complete disruption of the operation of a small team which was occurring because of the neglect of the standard of diving patterns could only result in a great deal of further trouble. There was therefore a considerable tightening up of all safety procedures, and all further diving in the next period between March and [April 1970] was worked strictly under the United States Navy Standard Air-Decompression Tables with surface interval credit tables and repetitive dive time-tables.
Each diver was provided with a depth gauge and complete records of dive times and depths were recorded in a log book. This system prevailed for a month during which time 278 hours of time were recorded.

This system of diving in salvage circumstances has grave disadvantages. Firstly on a salvage operation it is extremely difficult for any diver to perform one long dive at one consistent depth. He must move around varying his depth and position, he may have to return to the surface for different articles of equipment, and therefore may involve himself in a pattern of repetitive dives which complicate his decompression schedule to a considerable degree. Maximum depths and maximum times are routinely used for the calculation of decompression schedules as they should be and very often from a commercial point of view the divers have ‘run out’ of diving time before the end of the working day. Furthermore calculations with repetitive dive sheets, three different diving tables, the calculations of surface interval credits, even the simple difficulty of pencil and paper work and minor arithmetic on a wet and windy diving platform are very prone to errors. It seemed to me that this would inevitably lead to a further crop of “bends” as well as having disadvantages from the commercial point of view to the operators. I therefore recommended

1. the use of decompression meters for each individual diver suggesting that, together with their use, log books be maintained as accurately as possible
2. that repetitive dives be kept to the absolute minimum and of the briefest duration possible
3. that as far as possible, the decompression meters be used to indicate when the dive should be completed without the need for decompression stops.

From the institution of this pattern of diving operation in April 1970 until the end of July of 1973 something over 10,800 hours of diving time had been completed without any incident involving decompression sickness. One diver was killed by an underwater explosion on 25 October 1972, but apart from this accident the pattern of operations has been one of very considerable safety which bears very good comparison with any other similar pressure work. For instance in most pressure works involving caisson or tunnels an incidence of 2% bends rate is considered quite acceptable, and in many instances the number of cases has been considerably greater.

I would not, however, wish to recommend the uncritical use of decompression meters for commercial diving, nor indeed for any other sort of diving. They are but one method of monitoring a dive pattern and should in general be used with a full knowledge of other systems in addition. Certain points regarding the decompression meter have to be borne in mind.

1. It seems to be rather safer for shallower dives. The tables are safer for deeper dives. The crossover safety point seems to be in the region of about 90 fsw.
2. The meter is definitely less safe than tables when surface intervals occur over a period of longer than 6 hours.
3. Short, deep repetitive dives on the meter are likely to be dangerous.
4. There is a proven instrument variation.
5. The supposed 6 hour ‘memory period’ of the decompression meter is much less than the real excess nitrogen elimination period of the body – which is probably greater than 24 hours.

Decompression meters should only be used with a full understanding of their limitations. Nevertheless, the value of a simple instrument eliminating the need for calculation on a wet and windy surface with pencil and paper give it practical advantages which may in many cases outweigh its potential disadvantages. This is of particular significance in salvage work where in most cases the diving is likely to take place in depths less than 100 fsw.

I paid a visit to MV Holmpark myself in September and October of 1971 with a view to instructing the diving team in various safety procedures including the safe use of the decompression meter. I examined the site of work underwater and made continuing arrangements for the safety and medical supervision of the diving team, in addition to the provisions required by the Department of Labour code of practice for underwater operations. All divers were subsequently issued with a plastic card indicating vehicle management if decompression sickness might be suspected, and a list of telephone numbers relevant for assistance. A designated Medical Officer was appointed to conduct all routine pre-employment examinations and regular assessments on continuing fitness for diving. A high standard of fitness and safety has been maintained subsequently, apart from the one accident already mentioned. In addition even though a great deal of time has been spent by the divers in water possibly suffering from considerable contamination, they have been remarkably free of otitis externa.

Discussion

There are several points of interest in these two cases and the subsequent safety procedures adopted after their occurrence. Both cases were simple bends, classified currently as Type 1, without neurological or other involvement. Recently it has been our unfortunate lot to have to deal with a large number of very much more seriously injured divers, though in almost all cases these have been the result of much deeper dives for much briefer periods. Although both these divers exceeded the safe diving times for surfacing without decompression by a very great degree they did not receive the severe neurological involvement that has often occurred with other divers, even though in both cases there was a delay in treatment and an air evacuation involving some considerable additional decompression stress. Neither case responded adequately to the minimal-pressure oxygen recompression tables, and [both] required the older high-pressure air tables for their
adequate treatment. I personally ascribe this to the delay in
the institution of treatment, and although I have in all cases
tried to use the shorter tables initially, I have only found
them of benefit when instituted very rapidly after the onset
of symptoms. I think this displays some inadequacy in the
assessment of the tables when they were originally
introduced. It is obvious that, in testing therapeutic tables,
patients cannot be subjected to a delay in treatment. I think
it relevant that the diving pattern and pressure-time changes
involved were similar to those for caisson and tunnel workers
and that this case of aseptic necrosis should have occurred
in a diver performing such work. Finally although during
the past years the decompression meter has come in for a
great deal of criticism by professional and amateur divers
alike, this safety programme, when the instrument was used
with a fairly full knowledge of its limitations, shows how
valuable it can be. The salvage firm is intending to use the
same system for the diving on the salvage operation on the
Seawise University in Hong Kong.

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Dr Anthony George Slark, MB, BS (Lond), DPH, DIH, DObst,
F APHM, MRCGP, MFOM, deceased, at the time of writing
this report, was the Senior Medical Officer to the RNZN
Hospital HMNZS Philomel, Auckland, and Diving Medical
Advisor to the Department of Labour.

This verbatim report is published posthumously with the
kind permission of Eileen Slark and her family.

Automatic decompression meters
Carl Edmonds

Once again we hear of divers needing treatment for
decompression sickness which occurred following routine
decompression in accordance with an automatic
decompression meter. There have been three such cases
treated at the School of Underwater Medicine this year, and
the records show many others occurring over the last few
years since their general acceptance by the public as safe
alternatives to the “tables”.

It never ceases to amaze me how divers place such blind
faith in mechanical gadgetry! It seems that one can write
almost anything in a diving magazine, and there will be
gullible divers eager to accept every word as “gospel”. Such
has been the sales spiel on these DCMs (see Skin Diver

The DCMs in common use today make no allowances for
individual variability in physiology, and strict adherence
to the meter’s decompression schedule is bound to result in
some cases of decompression sickness (DS). Similarly there
is no allowance made for this factor with recognised RN
or USN decompression tables – however, the records here are
evident. Providing the table is followed exactly, the rate of
development of DS in divers is never greater than 2–3%.
I’m sure the record of divers on the DCMs is nowhere near
as good – certainly not in my experience.

For some time, we have been asked – especially by ex-
patients treated for DS after following the DCM schedules –
to evaluate these meters and publicise the results. At long
last we have managed to obtain 12 such meters (10
secondhand and two brand new and never exposed to
pressure/water) and have started evaluation testing. This
has been conducted on a basis compatible with practical
diving to depths varying in 20 ft increments from 60 ft to
200 ft. The results are far from being completed; however,
several significant features are already outstanding. These
are inconsistencies which are evident when the DCMs are
 tested in a ‘wet pot’ and show
• that the decompression schedules recommended by
individual DCMs for identical dive (depth/time) factors
vary considerably,
• that the decompression schedules recommended by the
same DCM for identical dives vary considerably – and
this followed a much longer than normal non-dive
period, and
• that the decompression schedules recommended by the
DCMs in some cases were more conservative (time wise)
than corresponding RN or USN tables; and yet in others
were far outside the limits of staging according to the
tables.

These features are apparent on single (“bounce”) dives –
repetitive dive testing has only just commenced, and results
are unknown as yet. The fact that variables such as
movement of the DCM (tapping, vibration, etc.) sunlight
(warmth, etc.) are known to markedly affect the non-dive
recovery period of the DCM, is sure to create interesting
variations when these tests are finalised.
In the meantime, it would appear that our best advice to divers concerning these DCMs is to never rely on them for any dive in excess of 120 ft or for any repetitive dives, and to follow the most conservative regime when the DCM is compared to a recognised decompression table, (i.e.) dive with both table and meter, and decompress according to the deepest first stop and longest decompression times.

Certainly these techniques will make diving more complex for “fools” – but anyone who dives to depths in excess of 100 ft and thinks all is rosy when following a DCM is a fool. Deep diving in a hostile environment requires careful planning and thoughtful techniques, and no mechanical mechanism exists which can always reliably predict decompression schedules for divers at various depths for variable periods. Surely, it is safer to err conservatively and stick to the “deepest depth X longest time” method. There are many ex-patients who can recommend this practice from personal experience with DCMs which failed.

The full results of the tests on the DCMs will be printed in the SPUMS newsletter when completed.

This article is reprinted from Edmonds C. Automatic decompression meters. *SPUMS J.* 1973; 3: 9.

**Editor’s comment:**

Eileen Slark kindly donated all of her husband’s diving medical teaching slides, papers, case records and books to the Occupational Medicine Unit, Department of Medicine, The University of Auckland. The report above was found amongst these papers, whilst Carl Edmonds’ brief contemporaneous article on decompression meters was published over 30 years ago in this Journal. The SOS meter was often referred to in those days as the ‘Bendomatic’!

I felt the juxtaposition of the two articles would be interesting historically, and that it highlights the common disparity between theory and practice in diving. Edmonds’ research, particularly his detailed later work on the Orca EDGE™ computer, showed the unreliability of the early generations of dive computers (and made him no friends in the diving industry!). Nevertheless, divers got on with the job, utilising these tools, inadequate as they were, with seeming success. Tony’s report demonstrates why he was held in high regard in New Zealand by his peers, and by military, occupational and recreational divers alike.

*Mike Davis*

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**Cartoon by Peter Harrigan reproduced from the cover of the *SPUMS J.* 1987; 17 (3)**
Diabetes and recreational diving: guidelines for the future

Workshop proceedings, 19 June, 2005
Neal W Pollock, Donna M Uguccioni and Guy de Lisle

Guidelines for diabetes and recreational diving

A workshop addressing issues of diabetes and recreational diving was jointly sponsored by the Undersea and Hyperbaric Medical Society (UHMS) and Divers Alert Network (DAN) to bring together experts and interested parties from within and beyond the international diving community. The meeting was held on June 19, 2005 in Las Vegas, Nevada, USA, following the UHMS annual scientific meeting. The objectives of the workshop were to review the existing data and, as warranted by participant support, to develop consensus guidelines to address diabetes and recreational diving. More than 50 individuals from seven nations, mostly clinicians and researchers, participated in the discussions.

Limitations: 1) The discussion was restricted to recreational diving. The issues concerning professional diving require future, separate deliberations. 2) This is a set of guidelines, not rules. The participants agreed that appropriate and justifiable differences in acceptable procedures may exist and that interest groups must have the flexibility to use the guidelines as they best serve their community’s needs.

The guidelines were divided into three sections: 1) selection and surveillance of people with diabetes in scuba diving; 2) scope of diving by people with diabetes; and 3) glucose management on the day of diving. Individual divers must bear responsibility for their health and safety and for adherence to established guidelines developed to improve their protection and that of their dive partners. Divers with diabetes are encouraged to participate in relevant research studies to expand the data available concerning diving with diabetes. Anyone with questions should consult with physicians knowledgeable in both diving medicine and diabetes care.

Section 1. Selection and surveillance

Those evaluating persons with diabetes for medical fitness to dive must first ensure that no other exclusionary conditions (e.g., epilepsy, pulmonary disease) exist. The physiological demands of diving must then be considered. Coronary artery disease is a leading cause of death in the largely non-diabetic diving population. Immersion may result in increased myocardial wall stress. There may also be a reduced awareness of ischaemic symptoms. People with diabetes are at higher risk of medical complications such as myocardial infarction, angina and hypoglycaemia than the general diving population. Such risks are exacerbated by the fact that many dive sites are quite isolated from medical aid. While only some medications increase the risk of hypoglycaemia, all persons with diabetes are at risk of secondary complications of the disease.

Recreational scuba diving may be undertaken by candidates otherwise qualified to dive who use medication (oral hypoglycaemic agents [OHAs] or insulin) to treat diabetes provided the following criteria are met.

1.1. Age 18 years and over (limit may be lowered to 16 years if special training* is available)
*special training will include dive training programs designed specifically to meet the education needs of individuals with diabetes and, desirably, to include participation by parents and/or responsible family members or guardians.

1.2. For a new diver at least three months have passed since the initiation or alteration of treatment* with OHAs or one year since the initiation of treatment with insulin. An established diver using OHAs who is started on insulin should wait at least six months before resuming diving.
*“alteration of treatment” is defined as a change in medication(s) or dosage(s) that could result in significant deviations from current status (changes likely to include only moderate change from current status would be described as “adjustment of treatment”).

1.3. There should have been no episodes of hypoglycaemia or hyperglycaemia requiring intervention from a third party for at least one year, and no history of hypoglycaemia unawareness. Note: certain OHAs (e.g., metformin, acarbose), when used on their own, do not predispose to hypoglycaemia.

1.4. Glycosylated haemoglobin (HbA1c - a measure of plasma glucose stability over the past two to three months) should be <= 9% when measured no more than one month prior to initial assessment and at each annual review. If HbA1c > 9% the diver should contact his/her diabetes specialist for further evaluation and modification of therapy.

1.5. There should be no: retinopathy worse than nonproliferative; significant autonomic or peripheral neuropathy; nephropathy causing proteinuria; coronary artery disease or significant peripheral vascular disease. Patients with retinopathy, peripheral vascular disease and/or neuropathy have a higher risk of sudden death due to coronary artery disease. Retinal haemorrhage could be
precipitated by small changes in mask pressure during descent and ascent or equalizing manoeuvres. Patients with neuropathy may experience exaggerated hypotension when exiting the water. Peripheral vascular disease may alter inert gas washout and predispose an individual to limb decompression sickness.

1.6. No more than two months prior to the first diving medical assessment and at each annual evaluation, a review is conducted by the candidate’s primary care physician (knowledgeable in treating diabetes) who must confirm that: criteria 1.3 – 1.6 are fulfilled; the candidate demonstrates accurate use of a personal blood glucose monitoring device; and that the candidate has a good understanding of the relationship between diet, exercise, stress, temperature, and blood glucose levels.

1.7. No more than two months prior to commencing diving for the first time and at each annual review, a diving medical examination is completed, preferably by (or in consultation with) a doctor who has completed an accredited postgraduate diving medical examiner’s course*. The review report completed by the primary care physician must be available. It is strongly recommended that formal evaluation for silent ischaemia be undertaken for candidates over 40 years in accordance with US American Heart Association/ American College of Cardiology or equivalent guidelines. *any accredited course (one certified as fulfilling certain standards by a national and/or regional professional association) in diving medicine is acceptable

1.8. At the diving medical examination, the candidate acknowledges in writing the receipt of and intention to use the diabetic diving protocol; the need to seek further guidance if there is any material that is incompletely understood; and the need to cease diving and seek review if there are any adverse events associated with diving suspected to be related to diabetes.

1.9. Steps 1.1 – 1.8 must be completed annually, using the same physicians where possible. After the initial evaluation, periodic surveillance for silent ischaemia can be in accordance with accepted guidelines for evaluation of diabetics.

Section 2. Scope of diving

Persons with diabetes selected according to Section 1 of this document who satisfactorily complete a recognized diver training course are considered suitable for recreational diving. The following stipulations and strong recommendations regarding diving activity and methods apply.

2.1. It is recommended that dives do not involve depths greater than 30 meters of sea water (100 fsw), durations longer than one hour, compulsory decompression stops, or take place in overhead environments. The depth limit is to avoid situations in which narcosis could be confused with hypoglycaemia. The time limit is to moderate the time blood glucose would remain unmonitored. The decompression and overhead environment limits are to avoid situations in which direct and immediate access to the surface is not available.

2.2. Divers with diabetes should dive with a buddy/leader who is informed of their condition and is aware of the appropriate response in the event of a hypoglycaemic episode. It is recommended the buddy does not have diabetes.

2.3. It is recommended that divers with diabetes avoid combinations of circumstances that might be provocative for hypoglycaemic episodes such as prolonged cold and arduous dives.

Section 3. Glucose management on the day of diving

Divers with diabetes who are selected according to Section 1 of this document, and who participate in appropriate diving activity as specified in Section 2, should use a protocol to manage their health on the day of diving. Note: the blood glucose monitoring protocols are applicable to people with diabetes whose medication may put them at risk of hypoglycaemia.

3.1. For every day on which diving is contemplated, the diver should assess him or herself in a general sense. If he or she is uncomfortable, unduly anxious, unwell in any way (including seasickness), or blood glucose control is not in its normal stable pattern, DIVING SHOULD NOT BE UNDERTAKEN.

3.2. The suggested goal for the diabetic approaching any dive is to establish a blood glucose level of at least 150 mg.dl⁻¹ (8.3 mmol.l⁻¹), and to ensure that this level is either stable or rising before entering the water. The workshop recommends that this be determined by three measurements of blood glucose, ideally taken 60 minutes, 30 minutes and immediately prior to diving. Diving should be postponed if blood glucose is < 150 mg.dl⁻¹ (8.3 mmol.l⁻¹), or there is a fall between any two measurements.

   a. Where relevant, strategic and individually tailored reductions in dosages of OHA medication or insulin on the evening prior or on the day of diving may assist in meeting these goals. Initial testing of individual protocols should be conducted under very controlled circumstances.

3.3. It is recommended that diving should be postponed or cancelled if blood glucose levels are higher than 300 mg.dl⁻¹ (16.7 mmol.l⁻¹).

3.4. Divers with diabetes should carry oral glucose in a readily accessible and ingestible form at the surface and
Executive summary

Historically, the diving medicine community has maintained a conservative position and concluded that insulin-requiring diabetes mellitus (IRDM) should be an absolute contraindication for participation in scuba diving. Dissent for this view has grown over the last 20 years. Recognizing that a substantial number of divers are diving successfully with diabetes – either openly or surreptitiously – has led many to believe that it is time to acknowledge this fact and reexamine the position concerning diabetes and diving.

This diabetes and diving workshop was jointly sponsored by the Undersea and Hyperbaric Medical Society (UHMS) and the Divers Alert Network (DAN) to bring together experts and interested parties from within and beyond the international diving community. Co-organizers were Dr Guy Dear, Dr Neal Pollock and Ms Donna Uguccioni. The meeting was held on June 19, 2005 in Las Vegas, Nevada, USA, following the UHMS annual scientific meeting. The objectives of the workshop were to review the existing data and, if deemed appropriate by discussants, to produce consensus guidelines addressing diabetes and recreational diving. More than 50 individuals from seven nations, mostly clinicians and researchers, participated in the discussions. The list of participants and their affiliations are found at the end of the proceedings document.

Nine invited speakers described data and experience gathered from around the world. Dr Guy Dear (USA) provided the opening remarks. Mr Steve Prosterman (USVI) provided an invaluable description of his personal experience both with diabetes and with diabetes and diving. Dr Eugenio Cersosimo (USA) presented an overview of the current state of the art in clinical management of diabetes mellitus. Dr Chris Edge (UK) reviewed 14 years of data, totaling approximately 14,000 dives, from United Kingdom divers diving with diabetes. Dr Dan Lorber (USA) represented the American Diabetes Association and presented an overview of discrimination and legal advocacy issues pertinent to persons with diabetes. The final paper appearing in this document was edited and approved by the ADA advocacy group. Ms Donna Uguccioni (USA) reviewed 12 years of data gathered through DAN-affiliated efforts, including surveys, workshops and observational studies. Dr Duke Scott (USA), the medical director for the YMCA SCUBA program, described the American YMCA program that has been used to train persons with diabetes to dive for the past 10 years. Dr Alexis Tabah (France) shared research data from two field studies on divers with diabetes conducted in France and reviewed the recently developed national regulations allowing recreational diving by persons with diabetes. Dr Warren Silberman (USA) described the US Federal Aviation Administration’s nine-year-old policy allowing special issuance of medical certificates to individuals with diabetes for third-class (noncommercial) aviation licenses. Dr Simon Mitchell (NZ) closed the presentation portion of the meeting by delivering a draft list of guidelines for diving with diabetes developed from the published literature.

The edited transcript of the workshop reveals the depth of discussions and controversy surrounding each of the guidelines presented below. Some points were easily settled and others more contentious, but all were finally decided through compromise and consensus. The general level of agreement for each point is indicated in this summary.

The workshop participants agreed that the available data supported the position that at least some individuals with diabetes might reasonably be allowed to dive. There was no open dissent on this fundamental issue. The discussion focused on the specifics of who and how.

Two important issues were raised at the start of the discussion. The first concerned the scope of the deliberations. It was agreed that the discussion was to be

during all dives. It is strongly recommended that parenteral glucagon is available at the surface. The dive buddy or other person at the surface should be knowledgeable in the use of glucagon. If symptoms or indications of hypoglycaemia are noticed underwater, the diver should surface, establish positive buoyancy, ingest glucose and leave the water. An informed buddy should be in a position to assist throughout this process. Use of an “L” signal with the thumb and index finger of either hand is recommended as a signal for suspected hypoglycaemia.

3.5. Blood glucose levels should be checked at the end of every dive. Appropriate response to the measured level can be determined by the individual mindful of his or her plans for the rest of the day. It should be noted that the requirements for blood glucose status outlined in 3.2 remain the same for any subsequent dive. In view of the recognized potential for late decrements in blood glucose levels following diving it is strongly recommended that the level is checked frequently for 12-15 hours after diving.

3.6. Divers with diabetes are strongly recommended to pay particular attention to adequate hydration on days of diving. Elevated blood glucose will lead to increased diuresis. While the data are limited, there is some evidence from divers with diabetes that an increase in haematocrit observed post-dive (suggesting dehydration) can be avoided by deliberate ingestion of fluid.

3.7. Divers with diabetes should log all dives, associated diabetic interventions and results of all blood glucose level tests conducted in association with diving. This log can be used to refine future planning in relation to diving.
limited to recreational diving. The issues concerning professional diving require future, separate deliberations. The second issue concerned the nature of the product that would be produced by the group effort. It was agreed that a set of guidelines, not rules, would be generated. The participants agreed that appropriate and justifiable differences in acceptable procedures may exist and that interest groups must have the flexibility to use the guidelines as they best serve their community’s needs.

The draft list delivered by Dr Mitchell served as a “straw man” to guide the discussion. The consensus guidelines, like the draft form, were grouped under three sections: selection and surveillance, scope of diving, and glucose management on the day of diving.

The selection and surveillance section began with general text indicating the importance of screening for other exclusionary conditions (e.g., epilepsy, pulmonary disease) and careful consideration of the context in which diving might be conducted. This includes immersion, the potential for extremely remote diving locations, and the high normal risk of cardiac involvement in diving fatalities. The section then addressed limits on age (18 years or older with the possibility of lowering to 16 years with special training), frequency of medical evaluation (at least annually), minimum periods of time from point of initiation or alteration of treatment to start or return to diving (three months from initiation or alteration of treatment with oral hypoglycaemic agents and one year since the initiation of treatment with insulin), allowable history of hypoglycaemic or hyperglycaemic events requiring third-party intervention (none within past year), hypoglycaemia unawareness (no history allowed), recent glycosylated haemoglobin (HbA1c) scores (further evaluation and possibly modification of therapy recommended for values > 9 percent), and secondary complications (none can be significant). The section also addressed the importance of having candidates demonstrate a good understanding of diet, exercise, stress, temperature and blood glucose levels and the need for silent ischaemia screening. Finally, the section addressed the need to have candidates agree to follow diabetic diving protocols and to stop diving and seek review for any adverse events that may be related to diabetes.

Several aspects pertaining to the minimum age for training were discussed. The merits of involving family members in training and in providing positive reinforcements to persons with diabetes were recognized. The need to be consistent with applicable public rules was also discussed.

The selection of appropriate minimum durations between initiation or alteration of treatment was contentious. Discussants favored a variety of intervals. The final wording reflected the more conservative position.

The importance of disqualification based on recent history of extreme hypoglycaemia, hyperglycaemia or hypoglycaemia awareness were widely accepted. Similarly, the importance of a solid understanding of the disease, personal responsibility and a willingness/ability to conduct appropriate self-monitoring were all widely accepted. The option to recommend disqualification based on a history of emergency visits to hospital for any condition related to the diabetes was discussed and rejected.

The necessity for an HbA1c criterion was contentious. Some felt that it was not an appropriate criterion; others preferred a range of high and low cutoff values. Key considerations included recognition that the tightest control might be associated with a greater frequency of hypoglycaemic events and the utility of the measure for counseling purposes. The final wording reflected a relatively inclusive limit.

The discussion of secondary complications of diabetes reflected the importance of monitoring and protecting the long term health of persons with diabetes. The relatively high frequency of cardiac involvement in diving incidents and the potential for accelerated development of coronary artery disease in persons with diabetes was addressed with a strong recommendation for silent ischaemia screening for candidates over 40 years of age. The guideline text regarding secondary complications and silent ischaemia screening was kept general in recognition of the limitations of available research data and potential regional/national differences in screening and evaluation standards. This section is expected to evolve as additional data become available.

The value of annual medical evaluation and the importance of the diver taking personal responsibility in managing his or her disease were generally accepted. There was discussion regarding the appropriate recommendations for physician training. While the abilities of fully trained diabetologists and diving medical officers were appreciated, practical limitations on the availability of specialty-trained physicians were also recognized. It was decided that accepting physicians knowledgeable in treating diabetes and physicians who had completed any post-graduate course in diving medicine was appropriate at this time.

The scope of diving section addressed limits on dive depth (100 fsw [30 msw]), decompression obligation and overhead environments, dive time (< 60 min), the need to inform dive partners of their condition and the appropriate response to adverse events, the diabetic status of the buddy diver (recommended to not have diabetes), and recommendations on avoiding situations that may promote or exacerbate hypoglycaemic events.

The discussants widely agreed that divers with diabetes should avoid situations which restrict direct access to the surface (notably dives with obligatory decompression or in overhead environments), those that could create conditions potentially confused with hypoglycaemic symptoms (specifically nitrogen narcosis), and those expected to
Table 1: Guidelines for recreational diving with diabetes - summary form

Selection and surveillance
- Age >=18 years (>=16 years if in special training program)
- Delay diving after start/change in medication
  - 3 months with oral hypoglycaemic agents (OHA)
  - 1 year after initiation of insulin therapy
- No episodes of hypoglycaemia or hyperglycaemia requiring intervention from a third party for at least one year
- No history of hypoglycaemia unawareness
- HbA1c <= 9% no more than one month prior to initial assessment and at each annual review
  - values > 9% indicate the need for further evaluation and possible modification of therapy
- No significant secondary complications from diabetes
- Physician/Diabetologist should carry out annual review and determine that diver has good understanding of disease and effect of exercise
  - in consultation with an expert in diving medicine, as required
- Evaluation for silent ischaemia for candidates > 40 years of age
  - after initial evaluation, periodic surveillance for silent ischaemia can be in accordance with accepted local/national guidelines for the evaluation of diabetics
- Candidate documents intent to follow protocol for divers with diabetes and to cease diving and seek medical review for any adverse events during diving possibly related to diabetes

Scope of diving
- Diving should be planned to avoid
  - depths > 100 fsw (30 msw)
  - durations > 60 min
  - compulsory decompression stops
  - overhead environments (e.g., cave, wreck penetration)
  - situations that may exacerbate hypoglycaemia (e.g., prolonged cold and arduous dives)
- Dive buddy/leader informed of diver’s condition and steps to follow in case of problem
- Dive buddy should not have diabetes

Glucose management on the day of diving
- General self-assessment of fitness to dive
- Blood glucose (BG) >=150 mg.dl⁻¹ (8.3 mmol.l⁻¹), stable or rising, before entering the water
  - complete a minimum of three pre-dive BG tests to evaluate trends
    - 60 min, 30 min and immediately prior to diving
  - alterations in dosage of OHA or insulin on evening prior or day of diving may help
- Delay dive if BG
  - < 150 mg.dl⁻¹ (8.3 mmol.l⁻¹)
  - > 300 mg.dl⁻¹ (16.7 mmol.l⁻¹)
- Rescue medications
  - carry readily accessible oral glucose during all dives
  - have parenteral glucagon available at the surface
- If hypoglycaemia noticed underwater, the diver should surface (with buddy), establish positive buoyancy, ingest glucose and leave the water
- Check blood sugar frequently for 12-15 hours after diving
- Ensure adequate hydration on days of diving
- Log all dives (include BG test results and all information pertinent to diabetes management)

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was made that two divers with diabetes may be diving in a larger group. The final wording of the recommendation favored a conservative position.

The glucose management on the day of diving section began by noting that the blood glucose monitoring protocols are applicable to people with diabetes whose medication may put them at risk of hypoglycaemia. The section then addressed the importance of self-assessment to ensure readiness to dive, as recommended for all divers, and several procedures specific to diabetes management. Advance preparation included individually tailored pre-dive modification of oral hypoglycaemic agents or insulin and carbohydrate ingestion, attention to hydration, and dive modification of oral hypoglycaemic agents or insulin.

Controversy surrounded the reasonable frequency of pre-dive blood glucose measures, the need to specify pre-dive blood glucose ranges, the optimal and acceptable ranges of pre-dive blood glucose, and the appropriate duration of post-dive blood glucose monitoring. Arguments for recommending minimal obligatory monitoring and greater freedom for the diver were largely based on the record of relatively trouble-free diving by minimally monitored persons with diabetes registered in the United Kingdom. Arguments for greater obligatory monitoring and tighter controls favor the potential for the guidelines to be more useful to persons, both divers with diabetes and medical professionals, who may have less experience with diabetes management and/or diving. The final wording of the recommendations reflected the conservative position of requiring repeated blood glucose tests and definitive minimum and maximum values.

The draft text of the guidelines was completed by the end of the workshop. The draft text was refined after the meeting by the workshop planners. The refined text and an edited transcript of the discussion were then distributed to participants electronically. Each was invited to provide comment. Changes were circulated to stimulate further electronic discussion. The guidelines provided at the beginning of this proceedings document represent the final text produced after integration of all input received. An abbreviated version of the final guidelines is in Table 1.

The participants in this workshop viewed the guidelines as a work in progress. We fully expect further refinements or even substantial modifications as our understanding of the issues involved in diving with diabetes evolves. It is important that any individual who has questions should consult with physicians knowledgeable in both diving medicine and diabetes care.

Future progress will be facilitated by efforts in two directions. The first is continued support and promotion of initiatives to collect data relevant to diabetes and diving. The second is development of programs and relationships to educate individuals with diabetes who are diving or interested in diving and those who might be professionally involved with divers with diabetes. The latter group includes certifying agencies, dive professionals, medical monitors addressing qualification issues and emergent needs, and the general diving public.

Neal W Pollock, PhD, Proceedings Editor and Co-Organizer, Center for Hyperbaric Medicine and Environmental Physiology, Duke University Medical Center, Durham, NC 27710, USA
Donna M Uguccioni, MS, Co-Organizer, Divers Alert Network, Durham, NC 27705, USA
Guy de Lisle Dear, MA, MB, FRCA, Chair and Co-Organizer, Department of Anesthesiology, Duke University Medical Center, Durham, NC 27710, USA

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Scuba diving, diabetes, blood sugar level, fitness to dive, DAN, meeting, reprinted from
Hidden dangers

Contaminated water diving: the risks divers don’t want to acknowledge

Steven M Barsky

Many commercial divers are unaware of the dangers of diving in polluted water. Some bodies of water don’t appear polluted, yet have high levels of biological or chemical contamination. In other environments, divers sometimes mistakenly believe that the water itself will dilute the hazard to a low level. In both settings, divers can be dead wrong.

The same hazardous materials that concern haz-mat personnel topside should concern divers underwater. These hazards include biohazards, toxic chemicals, and radiation. However, the situations that divers encounter these hazards in underwater are very different from those on the surface.

The main difference in dealing with a hazardous material underwater is that in many cases, the hazardous material floats in the water around the diver. This means that unless the diver equips himself properly, the material may enter the diver’s mouth through the regulator in his helmet. It may also get in his eyes through leaks in a band-mask hood or a helmet’s neck dam, and touch his skin through his wet suit. Compare this to a liquid spill topside, where the chemical puddles in the street, and it’s easy to appreciate the increased risks.

Toxics that float on top of the water, such as gasoline, also present a serious hazard to the diver. The diver must pass through them to dive or exit the water. Substances that sink in water are those most likely to collect as pockets of pure chemical substance on the bottom. Concentrated chemicals are obviously very hazardous.

Aside from the risks, the biggest problem in contaminated water diving is that many divers don’t want to acknowledge the dangers present at the sites where they dive. Conceding that these risks are present means that they must be dealt with intelligently and many divers don’t want to make the effort or spend the money to take the proper precautions. Over the short or long term, such disregard can have fatal effects.

Biological pollutants are the most common

Biological pollutants are probably the most common form of hazardous materials encountered by divers. Three main classes of biological contaminants are of concern to divers. Bacteria are single celled creatures that exhibit characteristics common to both plants and animals. Protozoans are single celled animals. Viruses are organisms that take over the chemistry of a host cell in living creatures to reproduce themselves.

Faecal coliforms are a disease-producing bacteria found in human and animal faeces. They are universally present in the water wherever there is raw sewage, or inadequate sewage treatment. The maximum safe level of this organism is considered to be 200 organisms per 100 milliliters of water. Swallowing water that contains faecal coliforms can produce severe, disabling diarrhoea. It might not kill you, but it will result in lost time from work.

Whenever heavy rains fill storm drains and cause waste treatment plants to exceed their capacity, millions of gallons of raw sewage spill into nearby waterways, sometimes closing beaches for several weeks. Such occurrences are common throughout the United States and other countries.

A commercial diver who dives in a waterway that contains high numbers of faecal coliforms should be equipped with the right equipment. Ordinary commercial diving gear is usually not enough. In the United States, even many public safety divers (fire, sheriff, police) now wear vulcanized rubber dry suits and full-face masks or diving helmets for protection from biological contaminants.

If faecal coliforms are present, it's a safe bet there are probably several other forms of biological pollution as well. Other dangerous bacteria include cholera, *Vibrio vulnificus* and *Aeromonas hydrophilla*. Cholera is a good example of a bacteria that can survive in sea water.

*Vibrio vulnificus* is an extremely potent marine bacteria that can also cause death. It enters the body through the mouth or raw wounds. *Aeromonas hydrophilla* also infects open cuts in the body and is commonly found in harbour waters. *Aeromonas* infections have been fatal if not properly treated.

Like bacteria, many protozoans pose serious threats to divers. For example, eight different species of *Acanthamoeba* occur in polluted waters. This deadly single celled organism causes inflammation of the spinal cord, with death as the end result. *Giardia lamblia*, another protozoan, causes intestinal pain, diarrhoea, and high fever.

Today, there are almost no streams in even remote areas that do not contain *Giardia*. This comes as a result of the high number of campers and backpackers using these areas. It is unsafe to drink water from any lake or stream in these areas unless it is treated. It is equally unsafe to swim or dive in these waters and accidentally swallow any liquid.
One of the most commonly known viruses, Hepatitis type A survives outside the body in both fresh and salt water. In Hepatitis A, the subject’s liver will become inflamed. Like other disease producing organisms that spread through contact with raw sewage, hepatitis can be found in faecal matter.

**Chemical hazards**

When divers think of hazardous materials emergencies, they often think about accidental spills of toxic chemicals. However, in many situations, divers also face serious threats from low level, long term pollution of waterways. Less obvious threats lurk in the form of pesticides and fertilizers that have drained into irrigation ditches or even water traps on golf courses.

A chemical hazard commonly found in all harbours and marinas is the variety of residues from boat bottom paints that have been used over the years. These bottom paints were designed to kill or inhibit the growth of marine life. They have been used on both large and small vessels. The same chemicals that discourage marine growth are hazardous to humans.

One of the primary components of these anti-fouling paints is an organotin compound known as tributyltin, more commonly known as “TBT”. There are 20 TBT compounds; 9 are used in boat bottom paints.

TBTs dissolve into fats, giving them the ability to move across the membranes of living cells. This trait is what makes them effective in killing marine organisms, such as barnacles. TBT tends to collect in the silt found on the bottom of harbours.

Almost all the research that has been done on TBTs has concentrated on the effect of these chemicals on marine creatures. However, in a report by the Brookhaven National Laboratory in the US, they note that chemicals in this class have toxic effects on the human central nervous system, blood, liver, kidneys, heart, and skin.

More alarmingly, the scientists noted that while people react to a single acute dose of TBTs, repeated sub-toxic doses also produce negative reactions. This suggests a cumulative effect, where low doses keep adding up in a diver’s body after repeated exposures.

Since many commercial dives take place in harbours, TBTs should be of concern to divers and dive supervisors, especially divers working on ship’s hulls. A scientist for the US Environmental Protection Agency (EPA) has labelled TBT as the “most toxic chemical ever deliberately added to the marine environment”. In 1988, the EPA banned the use of TBTs on non-aluminum vessels under 82 feet in US waters. Tributyltin use is restricted in some countries.

Although tributyltin breaks down in clear waters, it persists much longer in murky harbour waters. The by-products of TBT’s decay are also harmful. It may be years after TBT is banned worldwide before it no longer can be detected in the marine environment.

PCBs (Polychlorinated biphenyls) also pose serious potential threats to divers. Although PCBs are now banned in many countries, they were widely used in electrical and hydraulic equipment, paints, plastics, and other compounds. PCBs still continue to pollute many sites and numerous divers have been exposed to PCBs.

Divers who work around wooden piers and wharves should also beware of the dangers of creosote. Many wooden pilings are treated with creosote to prevent wood decay. Creosote also discourages marine worms from boring holes in the pilings. Unprotected divers can get chemical burns from brushing against pilings that are coated with creosote.

Certain chemicals are so dangerous that no diver should consider working around them. These chemicals include, but are not limited to, the following:

- Acetic anhydride
- Acrylonitrile
- Carbon tetrachloride
- Chlordane
- Cresol
- Dichloropropane
- Epichlorohydrin
- Ethylbenzene
- Methyl chloride
- Methyl parathion
- Perchloroethylene
- Styrene
- Trichloroethylene
- Xylene

Blood, urine, and stool samples are recommended pre and post dive when divers expose themselves to specific known chemical toxins. In addition, tests of the divers’ lung capacity are merited in cases where chemicals are known to affect the divers’ breathing ability.

It’s only in the last few years that the risks of diving in polluted water have been scientifically correlated with cancer in divers. Dr Elihu Richter, head of the unit of Occupational and Environmental Medicine at Hebrew University School of Public Health and Community Medicine in Jerusalem, was the principal author of a paper which detailed the chemical exposure of 682 Israeli Navy divers working in the Kishon River since 1948. The Kishon River is highly polluted with heavy metals and other contaminants.

Richter and his team found a much higher level of cancer in these divers than in other control populations. Exactly what caused the cancer in so many Israeli Navy divers is unknown, but there was a strong correlation between diving in the Kishon and cancer that cannot be explained by other causes.

In the United States we have anecdotal reports of cancer among dive team members in San Diego and Michigan, but there have been no studies undertaken to establish a scientific cause and effect relationship between diving and disease in most parts of the world.
By far, the largest source of pollution in most places is what is termed ‘non-point source pollution.’ This is a combination of everything that washes into our rivers, streams, and oceans from all ‘normal’ sources, including tire dust from cars, leaking oil and gasoline, faecal matter from household pets, pesticides and fertilizers used in agriculture as well as personal gardens.

**Radioactive hazards**

Radioactive substances are most likely to enter the marine environment through industrial accidents. However, the possibility also exists that someday terrorists may dump radioactive material into a drinking water supply or a harbor. Of course, some divers work inside nuclear plants, but they are usually well protected due to stringent monitoring in these environments.

**Thermal hazards exist too**

Aside from the risks of exposure to hazardous materials, dry suits and helmets also create thermal hazards for the diver. These hazards are exactly the same as haz-mat personnel face topside. They include fluid loss, heat cramps, and heat exhaustion.

During the time the diver dresses in before the dive, and during decontamination, heat stress can be a severe problem. If the diver works in cold water, some of the heat stress will be relieved during the dive. Moving from very warm surface climates into cold water, and back to hot surface temperatures, is stressful in itself.

If the diver works in warm water there is no relief from heat stress. Overheating may be a very real danger. Commercial divers who work in warm waters should carefully evaluate these conditions and plan dives accordingly.

In extended contaminated water diving operations in warm weather the diver’s physiology should be monitored. These include heart rate, body temperature, and weight. Measurements of these functions should be taken before and after diving.

Experiments have been conducted at the National Institute of Occupational Health, in Sweden, on the effectiveness of diver cooling using an ice filled vest. The divers in the study wore dry suits similar to those used for contaminated water diving.

Underneath the dry suit they wore a vest fitted with 46 small pockets, each of which was filled with a block of ice in a plastic bag. At water temperatures of 107 degrees F, the divers were able to complete dives that were 15-30 minutes longer when equipped with the ice filled vest. Further tests will need to be performed to determine safe exposure times for using such systems.

**Selecting the right equipment for contaminated water diving**

One of the basic tenets of contaminated water diving is to never dive unless you know exactly what pollutants are present. In reality, we know that many people do not take the time to find out what risks are present in the water. In certain circumstances, this could be fatal.

In order to protect yourself as fully as possible, the ideal combination of equipment is a vulcanized rubber dry suit with a mating helmet and dry gloves. Keep in mind that even with this gear, there is no one set of equipment that will protect you from all types of chemical hazards. There’s also no gear that will protect you from strong sources of radiation.

Free-flow helmets are generally considered very good protection from contaminated water because a positive pressure is maintained inside the helmet. However, demand helmets can also be used successfully, provided the breathing system is equipped with a redundant exhaust system to help prevent a back-flow of contaminants in the breathing system.

The interface between the diving helmet and the dry suit is extremely critical. Ideally, the helmet should mate directly to the suit, quickly and easily. Yet, the connection must be positive and secure. The system should be designed so that few, if any, contaminants are trapped between the helmet and the suit when the two are separated after the dive.

Dry suits for contaminated water diving should be made from a material that has a smooth, non-porous outer surface. The material must not absorb or trap contaminants. For diving in biologically polluted water, vulcanized rubber dry suits are usually considered the best choice.

Dry glove systems consist of a set of cuff rings as well as the gloves (or mittens). The cuff rings come in pairs of inner and outer rings. The inner ring is machined from hard plastic. It goes inside the sleeve of the dry suit where the sleeve attaches to the wrist seal. The outer ring is made from rubber. It slips over the sleeve and compresses the suit over the inner ring. The dry gloves or mittens snap into position over the outer ring.

If you are planning a dive in a chemical environment, it is essential to know the chemical compatibility of your equipment compared to the substances you will encounter. Some manufacturers have produced chemical compatibility tables that will give you the acceptable exposure time, in minutes, for their equipment. ‘Permeation time,’ which is the time it takes for a particular chemical to make its way through a piece of gear at the molecular level, is an essential issue for you to evaluate.
Evaluating tables like these is the only way to make an intelligent decision whether the risks on a particular dive are acceptable or not. Less scrupulous manufacturers have published results for their products that rate chemical compatibility as ‘good’ or ‘acceptable.’ Information like this is NOT adequate to plan a dive in a chemically contaminated environment. (Note: Chemical compatibility tables are available from some manufacturers as well as in the book, *Diving in High-Risk Environments*.)

Keep in mind that your exposure time is limited by the ‘weakest’ piece of equipment you plan to use. Since helmets and suits are made from many different types of materials, you must evaluate your entire diving ensemble, including suit, regulator diaphragm, exhaust valve, dry suit zipper, umbilical, etc. Making the wrong decision could cost you your life.

It’s also important to remember that the chemical tests conducted by all testing agencies are always conducted on new, unused equipment. Diving equipment that has been previously exposed to other chemicals may fail unexpectedly.

**Get the right training**

Training for contaminated water diving operations is a complex process. There is no single expert on this topic. Instead, it takes the combined talents of many different people to put together a strong training program. Ideally, the staff for a training course in contaminated water diving would include a biologist, a chemist, a haz-mat specialist, and a commercial diver.

The critical points in the hands-on training for this type of diving include properly dressing and leak testing the diver’s gear, and learning the correct procedures for decontamination following the dive. Since tenders may also need to be protected from fumes or chemicals encountered while tending the diver, they will need to be trained in the proper use of personal protective equipment topside.

**Acknowledge the risks**

Diving always involves risks and can never be made 100% safe. However, you increase your risks when you refuse to recognize that certain types of dives entail additional risks beyond what’s considered “normal.” Take the time to educate yourself and develop a healthy scepticism so that you’ll be properly prepared the next time someone asks you to dive in a high-risk environment.


**Address for correspondence:**
Steven M Barsky
Marine Marketing and Consulting
2419 E. Harbor Blvd. #149
Ventura, CA 93001, USA
Phone: +1-805-985-4644
E-mail: <smb@marinemkt.com>

**Key words**

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<allways@bigpond.com.au>
Cochrane corner

A systematic review of the use of hyperbaric oxygen therapy in the treatment of acute traumatic brain injury

Michael H Bennett, Barbara E Trytko and Benjamin Jonker

Key words
Cochrane library, brain injury, hyperbaric oxygen, reprinted from

Abstract

Introduction: We aimed to assess the randomised clinical evidence for the benefits and harms of adjunctive hyperbaric oxygen therapy (HBOT) for acutely brain-injured patients. HBOT can improve oxygen supply to the injured brain and reduce both cerebral oedema and cerebrospinal fluid pressure and might therefore result in a reduction in patient death and disability.

Methods: We performed a systematic search of the literature for randomised controlled trials and made pooled analyses of pre-determined clinical outcomes where possible using Cochrane Collaboration methodology. We included adults with serious closed head injury requiring admission to an intensive care environment and included trials must have compared a standard therapy with adjunctive HBOT to standard therapy alone following randomised allocation. We pre-determined important clinical outcomes and assessed them when reported in the primary studies.

Results: Four trials contributed to this review (382 participants, 199 receiving HBOT and 183 control). Pooled analysis suggested a significant reduction in the risk of dying when HBOT was added (RR 0.69, 95% CI 0.54 to 0.88, NNT = 7, P = 0.003), but no statistically significant increase in the chance of a favourable clinical outcome (RR 1.94, 95% CI 0.92 to 4.08, P = 0.08).

Conclusions: HBOT reduced the risk of death but did not clearly increase the chance of favourable clinical outcome. Routine application of HBOT to these patients should not be justified from this review. More research of high methodological rigour is needed in order to confirm or refute the findings of this review.

Introduction

Traumatic brain injury (TBI) is a significant cause of premature death and disability. There are at least 10 million new head injuries worldwide annually and these account for a high proportion of deaths in young adults.\(^1\,^2\) In the US, 2% of the population (5.3 million citizens) are living with disability as a result of TBI\(^3\) and this places considerable medical, social and financial burden on both families and health systems.\(^4\) Any intervention that may improve the chance of a good functional outcome is therefore worthy of study.

Hyperbaric oxygen therapy (HBOT) is one such intervention. HBOT is the administration of 100% oxygen at environmental pressures greater than 1 atmosphere absolute (ATA), an absolute pressure of 101.3 kPa. This involves placing the patient in an airtight vessel and increasing the pressure within that vessel while administering 100% oxygen for respiration. In this way, it is possible to deliver a greatly increased partial pressure of oxygen to the tissues. At 2 ATA (202.6 kPa) for example, patients with reasonable cardiopulmonary function will have an arterial oxygen tension of over 1000 mmHg, and a muscle oxygen tension around 221 mmHg.\(^4\,^5\) Administration of HBOT is therefore based on the potential for reversing tissue hypoxia and modifying secondary neurological effects.

Following primary injury, there is ongoing injury to the brain through a variety of mechanisms including hypoxia, reduced cerebral blood flow (ischaemia), release of toxic levels of excitatory neurotransmitters, impaired calcium homeostasis and elevated levels of cytokines (secondary injury).\(^6\,^7\) In addition oxygen extraction is increased in the hours following injury.\(^8\)

Hypoxic neurons performing anaerobic metabolism result in acidosis, unsustainable reduction in cellular metabolic reserve,\(^9\) loss of the ability to maintain ionic homeostasis, free oxygen radical accumulation, degradation of cell membranes and eventual secondary cell death.\(^10\,^11\) When hypoxia is severe enough, these changes occur rapidly, but there is some evidence that these effects can sometimes occur over a period of days.\(^12\)

A therapy able to increase oxygen availability in the early period following TBI may therefore improve long-term outcome. HBOT is also thought to reduce tissue oedema by an osmotic effect,\(^13\) and any agent that has a positive effect on brain swelling following trauma might also contribute
to improved outcomes. On the other hand, oxygen in high doses is potentially toxic to normally perfused tissue, and the brain is particularly at risk.\(^\text{14}\) HBOT may therefore do more harm than good in some patients.

Since the 1960s, there have been scattered reports that HBOT improves the outcome following brain trauma.\(^\text{15}\) HBOT has been shown to reduce intracranial pressure (ICP) in brain-injured patients,\(^\text{16,17}\) improve grey matter metabolic activity on SPECT scan,\(^\text{18}\) and improve glucose metabolism.\(^\text{19}\) Some studies suggest that any effect of HBOT may not be uniform across all brain-injured patients. For example, Hayakawa demonstrated that CSFP rebounded to higher levels following HBOT than at pre-treatment estimation in some patients, while others showed persistent reductions.\(^\text{17}\) It is possible that HBOT has a positive effect in a sub-group of patients with moderate injury, but not in those with extensive cerebral injury. Furthermore, repeated exposure to hyperbaric oxygen may be required to attain consistent changes.\(^\text{20}\)

Clinical reports have attributed a wide range of improvements to HBOT including cognitive and motor skills, improved attention span and increased verbalisation.\(^\text{16,18}\) These improvements are, however, difficult to ascribe to any single treatment modality because HBOT was most often applied in conjunction with intensive supportive and rehabilitative therapies.

The purpose of this review is to assess the randomised clinical evidence for the benefit or harm of adjunctive HBOT in the treatment of acute TBI. This paper is based on a Cochrane review first published in The Cochrane Library 2004, Issue 4. Chichester, UK: John Wiley & Sons, Ltd (www.thecochranelibrary.com). Copyright Cochrane Library, reproduced with permission. Cochrane reviews are regularly updated as new evidence emerges and in response to comments and criticisms. The Cochrane Library should be consulted for the most recent version of the review.

### Methods

It was our intention to identify and review all randomised controlled trials (RCTs) concerning the treatment with HBOT of any patient with TBI in the first days following injury. We included all trials using hyperbaric oxygen administered in a compression chamber above 1.5 ATA (152 kPa) and for treatment times between 30 and 120 minutes on at least one occasion. For the comparator therapy, we accepted any standard treatment regimen designed to maximise brain protection and promote recovery from TBI. We did not include studies where comparator interventions were not undertaken in a specialised acute care setting.

Specific search strategies were developed to identify eligible reports from database inception to August 2004 in MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials (CENTRAL) and the Database of Randomised Controlled Trials in Hyperbaric Medicine (DORCTHM). The latter is a specifically targeted database of clinical evidence in the field (<http://www.hboevidence.com>).

Medical subject headings (MeSH) and main key words used were ‘hyperbaric oxygenation’, ‘head injuries, closed’, ‘head injuries, penetrating’, ‘craniocerebral trauma’ and ‘coma- post head injury’, with variants of the main key words and free text terms also applied. No restrictions to language were made. Relevant hyperbaric textbooks, journals and conference proceedings were hand searched. Experts in the field were contacted for published, unpublished and ongoing RCTs. Additional trials were identified from the citations within obtained papers.

We pre-determined the following clinically important outcomes for assessment, and all included studies must have reported at least one of these: functional outcome measures (e.g. Glasgow Outcome Scale, GOS), death, activities of daily living (ADL) or quality of life (QALY) measures.

#### Table 1

Summary of Jadad score from\(^\text{21}\) (each criteria scores or deducts one point if satisfied, giving a quality score from zero to five)

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</thead>
<tbody>
<tr>
<td><strong>Randomisation</strong></td>
<td>The study is described as randomised, including using words such as ‘random’, ‘randomised’ or ‘randomly’</td>
</tr>
<tr>
<td>Additional Deduction</td>
<td>The method of randomisation is described and appropriate (e.g. use of random number table)</td>
</tr>
<tr>
<td><strong>Double blinding</strong></td>
<td>The study is described as double-blind</td>
</tr>
<tr>
<td>Additional Deduction</td>
<td>The method of double-blinding is described and appropriate (e.g. use of placebo or sham therapy)</td>
</tr>
<tr>
<td><strong>Description of withdrawals</strong></td>
<td>There is a description of any dropouts or withdrawals during the course of the study</td>
</tr>
</tbody>
</table>
addition we recorded the following indirect outcomes: intracranial pressure (ICP), magnetic resonance image (MRI) findings, computed tomography (CT) findings and cost-effectiveness. Any reported adverse events of HBOT were also recorded.

Each reviewer independently assessed the electronic search results and selected potentially relevant studies. Disagreements were settled by examination of the full paper and consensus. To assess methodological quality and detect potential sources of bias we applied the quality scale of Jadad (Table 1). We also recorded the adequacy of allocation concealment. If any relevant data were missing from trial reports, we attempted to contact the authors. To allow an intention to treat analysis we extracted the data reflecting the original allocation group where possible. Disagreements were again settled by consensus.

STATISTICAL ANALYSIS

Following agreement, the data were entered into Review Manager® 4.2.1. (Cochrane Collaboration, Oxford, UK). For dichotomous outcomes such as the proportion of participants who died, we calculated Relative Risks (RR) with 95% confidence interval (CI). A statistically significant difference from control was assumed when the 95% CI of the RR did not include the value 1.0. For continuous outcomes such as the mean change in ICP for each group, we calculated the mean difference (MD) between groups with 95% CI. We used a fixed-effects model where problematic heterogeneity between the studies was not likely and a random-effects model where such heterogeneity was likely. Heterogeneity was deemed problematic if the I² analysis suggested more than 30% of the variability in an analysis was due to systematic differences between trials rather than chance alone. Consideration was then given

<table>
<thead>
<tr>
<th>Study</th>
<th>Methods</th>
<th>Participants</th>
<th>Interventions</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artru 1976</td>
<td>Method of randomisation not</td>
<td>60 participants, 31 HBOT and 29 control. Inclusion depended on availability of chamber. Stratified into nine categories of severity and pathology.</td>
<td>Control: ‘Standard care’ included hyperventilation and frusemide. HBOT: above plus 2.5 ATA oxygen for 1 hour daily for 10 days, followed by 4 days rest and repeat if not responding.</td>
<td>Death Unfavourable outcome Adverse effects</td>
</tr>
<tr>
<td>Ren 2001</td>
<td>Method of randomisation not</td>
<td>55 participants, 35 HBOT and 20 control. Included: closed head injury with GCS &lt; 9. Randomised on day 3 post admission after condition stabilised.</td>
<td>Control: Standard care plus dehydration, steroids and antibiotics. HBOT: above plus 2.5 ATA for a total of 400 to 600 minutes every 4 days, repeated 3 or 4 times.</td>
<td>Favourable GOS Change in GCS</td>
</tr>
<tr>
<td>Rockswold 1992</td>
<td>Method of randomisation not clear, medical assessors blind. Jadad score 2.</td>
<td>168 participants, 84 HBOT and 84 control. Included: closed head injury with GCS &lt; 10 for &gt; 6 hrs, &lt; 24 hrs.</td>
<td>Control: ‘Intensive neurosurgical care according to a comprehensive protocol’. HBOT: above plus 1.5 ATA oxygen for 1 hour every 8 hours for 2 weeks or until waking or death (ave 21 treatments).</td>
<td>Death Favourable outcome (GOS 1 or 2) ICP Adverse events</td>
</tr>
</tbody>
</table>
to the appropriateness of pooling and meta-analysis. Number-needed-to-treat (NNT) with 95% CI was calculated when the relative risk estimates were statistically significant.

We planned sensitivity analyses for missing data and study quality. We also considered subgroup analysis based on age, oxygen dose, comparator therapy used, and the nature and severity of injury.

Results

THE INCLUDED STUDIES

The search in August 2004 yielded 23 articles of which seven were considered to be possible randomised human trials dealing with the treatment of TBI with HBOT. Two were excluded because they were incomplete reports of included trials, and one because it enrolled only participants with non-acute injuries. Four publications therefore met our inclusion criteria. One trial used a sequential system for allocation that may not have been truly random. The total number of participants enrolled was 382, 199 receiving HBOT and 183 control.

All four trials enrolled participants with closed head injury, but inclusion criteria varied. Rockswold accepted those with a Glasgow Coma Score (GCS) of less than 10 for between six and 24 hours, Ren accepted participants with a GCS of less than nine for up to three days after trauma. The other two older trials did not specify inclusion criteria, other than ‘closed head injury and comatose’. Treatment pressures (1.5 to 2.5ATA, or 152 to 253.3 kPa), time schedule (60 to 90 min), and number of sessions (10 to 40) of HBOT differed between studies. Similarly, there was some variation in comparator therapies and the time to final assessment. Individual study characteristics are given in Table 2.

No study described the method of randomisation, clearly concealed allocation from the individual responsible for randomisation or employed a sham therapy. Study quality was generally assessed as low and was not used as a basis for sensitivity analysis.

CLINICAL OUTCOMES

Statistical pooling was not possible for many of the pre-planned outcome measures due to lack of suitable data. Problems included the small number of studies, modest number of patients, and the variability in outcome measures employed. The data are summarised in Table 3.

PRIMARY OUTCOMES

Good functional outcome

Good functional outcome was defined in these studies as any one of the following: GOS < three, ‘return of consciousness’, ‘complete recovery’ or classified as ‘independent’. Two trials reported this outcome early (0 to 4 weeks) following the course of therapy and involved 159 participants. 29 (36%) were described as having a good outcome in the HBOT group versus 11 (14%) in the control group. Pooled analysis suggests however, that there is no significant difference between groups (RR with HBOT: 2.66, 95% CI 0.73 to 9.69).
95% CI 0.73 to 9.69, \( P = 0.06 \). There was evidence of significant heterogeneity between these studies (\( I^2 = 72\% \)) and this result is performed using a random effects model (Figure 1).

Ren reported a significant improvement in the chance of a good outcome at six months' review\(^{26} \) (RR 2.8, 95% CI 1.4 to 5.5, \( P = 0.004 \)), while at one year, Rockswold did not\(^{27} \) (RR 0.98, 95% CI 0.73 to 1.3, \( P = 0.87 \)). When combining all trials at final outcome, 109 participants (51%) in the HBOT group had a good outcome versus 61 (34%) of controls, however this difference was not statistically significant (RR 1.94, 95% CI 0.92 to 4.08, \( P = 0.08 \)). This result is very likely to be subject to important heterogeneity between trials (\( I^2 = 81\% \)) and should be interpreted very cautiously.

Subgroup analysis by treatment pressure suggested the application of a high treatment pressure (2.5 ATA or 253.3 kPa) was associated with a better outcome than the application of a low treatment pressure (1.5 ATA or 152 kPa) (high pressure RR 2.07, 95% CI 1.15 to 3.72, \( P = 0.003 \), low pressure RR 2.12, 95% CI 0.35 to 12.78, \( P = 0.11 \)). This result is unconvincing given the high probability of important heterogeneity remaining between the two low pressure trials (\( I^2 = 89\% \)) and the similar estimate of RR in these two groups.

### Mortality

Three trials reported this data at some time (Holbach at 12 days, Artru and Rockswold 1992 at 12 months) involving 327 participants. There was significantly increased mortality with control therapy (RR 1.46, 95% CI 1.13 to 1.87, \( P = 0.003 \)). Heterogeneity between studies was low (\( I^2 = 0\% \)). The NNT to avoid one death by applying HBOT was 7, 95% CI 4 to 22 (Figure 2).

No trials reported on activities of daily living, quality of life measures, CT or MRI findings, progress of GCS or cost-effectiveness.

### SECONDARY OUTCOMES

#### Intracranial pressure

Only Rockswold reported the effects of therapy on ICP.\(^{27} \) The effect of HBOT was complicated by a change in the experimental protocol during the period of recruitment. While overall there was no difference in the mean maximum ICP between the two groups (MD 3.1 mmHg lower with HBOT, 95% CI -9.6 mmHg to +3.4 mmHg), the authors noted higher than expected ICP in the early HBOT participants. As this was likely to represent pain from middle ear barotrauma (MEBT), the last 46 participants recruited to

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### Figure 1

Forest plot for risk of good outcome at final follow-up

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>HBOT</th>
<th>Control</th>
<th>RR (random)</th>
<th>Weight</th>
<th>RR (random)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nN</td>
<td>nN</td>
<td>95% CI</td>
<td>%</td>
<td>95% CI</td>
</tr>
<tr>
<td>Holbach 1974</td>
<td>16/49</td>
<td>3/50</td>
<td>18.09</td>
<td>5.44</td>
<td>[1.69, 17.51]</td>
</tr>
<tr>
<td>Artru 1976</td>
<td>13/31</td>
<td>8/29</td>
<td>25.04</td>
<td>1.52</td>
<td>[0.74, 3.13]</td>
</tr>
<tr>
<td>Rockswold 1992</td>
<td>44/84</td>
<td>44/82</td>
<td>31.26</td>
<td>0.98</td>
<td>[0.73, 1.30]</td>
</tr>
<tr>
<td>Ren 2001a</td>
<td>29/35</td>
<td>6/20</td>
<td>25.61</td>
<td>2.76</td>
<td>[1.39, 5.49]</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>199</td>
<td>181</td>
<td>100.00</td>
<td>1.94</td>
<td>[0.92, 4.08]</td>
</tr>
</tbody>
</table>

### Figure 2

Forest plot for risk of death at any time after enrolment

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>Control</th>
<th>HBOT</th>
<th>RR (fixed)</th>
<th>Weight</th>
<th>RR (fixed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>nN</td>
<td>nN</td>
<td>95% CI</td>
<td>%</td>
<td>95% CI</td>
</tr>
<tr>
<td>Holbach 1974</td>
<td>37/50</td>
<td>26/49</td>
<td>48.11</td>
<td>1.39</td>
<td>[1.02, 1.90]</td>
</tr>
<tr>
<td>Artru 1976</td>
<td>16/29</td>
<td>15/31</td>
<td>25.66</td>
<td>1.14</td>
<td>[0.70, 1.86]</td>
</tr>
<tr>
<td>Rockswold 1992</td>
<td>26/82</td>
<td>14/84</td>
<td>25.33</td>
<td>1.90</td>
<td>[1.07, 3.38]</td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>161</td>
<td>164</td>
<td>100.00</td>
<td>1.46</td>
<td>[1.13, 1.87]</td>
</tr>
</tbody>
</table>

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http://archive.rubicon-foundation.org
HBOT had pre-compression myringotomy tubes inserted to allow free equalisation of middle ear pressures. Comparing the standard care group with the HBOT subjects with and without myringotomy, there is a significant lowering of ICP with HBOT plus myringotomy, but no difference without myringotomy (MD with myringotomy -8.2 mmHg, 95% CI -14.7 mmHg to -1.7 mmHg, P = 0.01; without myringotomy MD +2.7 mmHg, 95% CI -5.9 mmHg to +11.3 mmHg, P = 0.54).

Adverse effects

Rockswold reported generalised seizures in two participants in the HBOT group versus none in the control group (RR 0.2, P = 0.3) and a further two with haemotympanum from MEBT (RR 0.2, P = 0.03).

Two trials reported participants with significant pulmonary effects.\(^{27,28}\) Rockswold reported ten individuals with rising oxygen requirements and infiltrates on chest x-ray, while Artru reported five patients with respiratory symptoms including cyanosis and hyperpnoea so severe as to imply ‘impending hyperoxic pneumonia’. Overall, therefore, 15 patients (13% of those receiving HBOT) had severe pulmonary complications while no such complications were reported in the standard therapy arm. This difference is statistically significant (RR 0.06, 95% CI 0.01 to 0.47, P = 0.007). There was no indication of heterogeneity between trials (\(I^2 = 0\%\)) and this analysis suggests we might expect to treat eight patients with HBOT in order to cause this adverse effect in one individual (NNH 8, 95% CI 5 to 15).

Discussion

This review has included data from four trials and we believe these represent all randomised human trials in this area, both published and unpublished, at the time of searching the databases. We found some evidence that HBOT reduces mortality following closed head injury, but cannot be confident that the addition of HBOT to standard therapy increases the chance of recovery to independence. The single trial looking at ICP as a proxy for beneficial effects did suggest that ICP was lower immediately following HBOT when patients had received middle ear ventilation tubes. These tubes avoid MEBT on compression – a highly painful and stimulating condition that might be expected to raise ICP, regardless of the underlying brain injury. Any clinical benefit may come at the cost of significant pulmonary complications. These complications are rare in general hyperbaric practice\(^ {10}\) and may be related specifically to the head injuries suffered by these patients.

Only 382 participants were available for evaluation using our planned comparisons, and meta-analysis was not appropriate or possible for a number of these. Other problems for this review were the poor methodological quality of these trials, variability and poor reporting of entry criteria, the variable nature and timing of outcomes, poor reporting of both outcomes and methodology and the long time period spanned by the four trials (27 years). In particular, there is a possibility of bias due to different times to entry in these small trials, as well as from non-blinded management decisions in all trials.

We had planned to perform subgroup analyses with respect to age, oxygen dose, nature of comparative therapies and the severity of injury. The paucity of eligible trials and poor reporting suggested the majority of these analyses would not be informative, and we only performed subgroup analysis with respect to treatment pressure for the proportion of individuals achieving a good outcome. No standard severity index was employed uniformly across these trials, no standard injury pattern was established, and only Rockswold and Ren described the time at which the inclusion criteria were applied.

While 13% of participants in two of these trials suffered significant pulmonary complications, this is unusual, and HBOT is generally regarded as a relatively benign intervention. There are few major adverse effects (pulmonary barotrauma, drug reactions, injuries or death related to chamber fire), and a number of more minor complications that may occur commonly. Visual disturbance, usually reduction in visual acuity secondary to conformational changes in the lens, is very commonly reported – perhaps as many as 50% of those having a course of 30 treatments.\(^ {31}\) While the great majority of patients recover spontaneously over a period of days to weeks, a small proportion of patients continue to require correction to restore sight to pre-treatment levels. The second most common adverse effect associated with HBOT is barotrauma, usually MEBT, although other sites include the respiratory sinuses and dental cavities. Most episodes of barotrauma do not require the therapy to be abandoned. Less commonly, perhaps once every 5,000 treatments, HBOT may be associated with acute neurological toxicity manifesting as seizure.\(^ {30}\)

While we have made every effort to locate further unpublished data, it remains possible that this review is subject to a positive publication bias, with generally favourable trials more likely to achieve reporting. With regard to long-term outcomes following HBOT and any effect on the quality of life for these patients, we have located no relevant data.

Conclusions

We conclude there is limited evidence that HBOT reduces mortality in patients with acute TBI, but no clear evidence of improved functional outcome. The small number of studies, the modest numbers of patients, and the methodological and reporting inadequacies of the primary studies included in this review demand a cautious interpretation. We do not believe routine use of HBOT for these patients is justified by this review.
There is a case for large randomised trials of high methodological rigour in order to define the true extent of benefit (if any) from the administration of HBOT. Specifically, more information is required on the subset of disease severity or classification most likely to benefit from this therapy and the oxygen dose most appropriate. Any future trials would also need to consider appropriate sample sizes with power to detect expected differences, appropriate and carefully defined comparator therapy, use of an effective sham therapy, effective and explicit blinding of outcome assessors, appropriate outcome measures including all those listed in this review, careful elucidation of any adverse effects and the cost-utility of the therapy.

Acknowledgements

We acknowledge the assistance provided by the Cochrane Injuries Group, and particularly of Katharine Ker and Paul Chinnock, in the production of this review.

The results of a Cochrane review can be interpreted differently, depending on people’s perspectives and circumstances. Please consider the conclusions presented carefully. They are the opinions of review authors, and are not necessarily shared by The Cochrane Collaboration.

References


Michael H Bennett, FANZCA, Senior Staff Specialist, Department of Diving and Hyperbaric Medicine, Prince of Wales Hospital and University of NSW, Sydney, Australia
Barbara E Trytko, FJFICM, Senior Staff Specialist, Departments of Intensive Care and Diving and Hyperbaric Medicine, Prince of Wales Hospital, Sydney, Australia
Benjamin Jonker, FRACS, Registrar, Department of Neurosurgery, Prince of Wales Hospital, Sydney, Australia

Address for correspondence:
MH Bennett, FANZCA
Department of Diving and Hyperbaric Medicine,
Prince of Wales Hospital,
Barker Street, Randwick,
NSW 2031,
Australia
Phone: +61-(0)2-9382-3880
Fax: +61-(0)2-9382-3882
E-mail: <m.bennett@unsw.edu.au>

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The poetry doctor

Beware below blues
The sea is full of danger.
For me it is a fact
For whenever I go diving
I always get attacked.

The lion fish is lurking
Looking oh so tame
As I guide it with my hand
To fit my photo frame.

The jelly fish drifts passively,
Its tentacles so slim,
Yet as I swim through their mass
They wrap around my limbs.

The octopus just ogles me,
So serene and calm
As I admire its blue rings
Whilst it nestles in my palm.

The cone shell waits so patiently.
It shows no fire or fear
As I pick and pocket it
As a souvenir.

The stone fish sits so stoically
With camouflage so neat
As I walk the shallow reef
With unprotected feet.

The hydroid seems so innocent
So soft and fine and thin
As I gently fin past it
And brush my ankle skin.

As the sharks patrol the reef
I watch them with alarm
As they speed at me bare teethed
My speared fish underarm.

I am so scared to dive below.
It’s full of dangerous things.
Please tell me how I can avoid
These bites and spines and stings?

I wrote this after brushing my ankle on a stinging hydroid. These stings always give me grief and afterwards I thought how stupid I am not to wear bootees every dive. A few days later I was bitten by a red back spider as I put my boot on in my shed. I was immensely grateful for the four ampoules of antivenene used to ease this particular reminder of how important it is to be cautious both in and out of the water.

John Parker
<www.thepoetrydoctor.com>
South Pacific Underwater Medicine Society Diploma of Diving and Hyperbaric Medicine

Requirements for candidates

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

1. The candidate must be medically qualified, and be a financial member of the Society of at least two years’ standing.

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 Hyperbaric Medicine Unit.

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, and in a standard format, for approval by the Academic Board 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.

Additional information

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

The Academic Board reserves the right to modify any of these requirements from time to time. The Academic Board consists of:

Dr Chris Acott, Education Officer, Professor Des Gorman and Associate Professor Mike Davis.

All enquiries should be addressed to the Education Officer:
Dr Chris Acott,
30 Park Avenue
Rosslyn Park
South Australia 5072
Australia
E-mail: <cacott@optusnet.com.au>

Key words
Qualifications, underwater medicine, hyperbaric oxygen, research

Minutes of the SPUMS Executive Committee Teleconference held on 9 October 2005

Opened: 0900 hr

Present: Drs C Acott (President), S Sharkey (Secretary), G Williams (Public Officer), D Smart (ANZHMG Representative), M Davis (Editor), C Lee (Committee Member), D Vote (Committee Member)

Apologies: Drs R Walker (Immediate Past-President), A Patterson (Treasurer)

1 Minutes of the previous meeting (31 July 2005)
Moved that the minutes be accepted as a true record. Proposed Dr Sharkey, seconded Dr Vote, carried.

2 Matters arising from the previous minutes
2.1 The issue of formalising the functions required of the SPUMS Administrator is progressing. Current roles and functions are to be reviewed by the Committee at the next meeting with a view to formalising this arrangement in the form of an independent contractor agreement. ACTION: All.
2.2 Finalisation of the final figures from the 2004 ASM remained outstanding in view of the absence of the Treasurer for further comment. Action: Dr Patterson to advise of final accounts for 2004 ASM in particular whether the refunds had been reflected in the P&L.

2.3 The irregularities in the 2005 ASM financial reports require investigation. ACTION: Dr Patterson to pursue this issue with the Convenor and Administrator.

2.4 Audit of SPUMS equipment being progressed. ACTION: Dr Sharkey.

2.5 Confirmation of status of overseas representatives required. ACTION: Dr Sharkey.

3 Annual Scientific Meeting 2006

3.1 Preliminary timetable was proposed and agreed. AGM on the Wednesday night, Gala Night on the Friday night with workshops on the Monday, Tuesday and Thursday nights.

3.2 Registration fees: $450 members; $570 non-members; $180 partners.

3.3 CME points from relevant colleges are being sought.

3.4 Proposed workshops include variety of airway and ventilation procedures. Assistance in workshop delivery by Anaesthetic members is welcome. Proposed presentations include diabetes, PFOs and other shunts, asthma, breath-hold diving and immersion physiology, obesity, airway devices and resuscitation, reverse dive profiles, evolving problem sessions (FTD and emergency management of diving presentations).

3.5 Dr Williams advised that Consumer Affairs had agreed to slight delay in this year’s AGM outside the rules.

3.6 2007 Scientific Meeting to be held in New Zealand – Convenor Dr M Davis; Co-convenor Dr S Mitchell. Meeting is confirmed for the third week in April 2007, venue is Tutakaka. The conference will have a predominantly physiological theme. Organisation of the 2007 conference is being progressed by Dr Davis.

4 Journal report

4.1 Discussions occurred regarding the issues relating to profit reduction due to lower membership numbers over last year. This included recognition of certain obstacles to be overcome for these reductions to be lessened. E.g., need to write personally to all old non-renewed members; need the new website to be up and running; possible need for the journal amalgamation to go ahead. In view of membership reduction and therefore financial considerations, Dr Davis declined the offer of an honorarium increase as editor at present.

4.2 Journal name update will take place in the New Year with the new volume. This will include the Australian National Library being informed and EMBASE Indexing.

4.3 CD production has been discussed with the printer. A searchable PDF CD covering the past 5 years is possible for A$900; additional to this, John’s 30 volumes will incur a small fee resulting in approximately $1000 total price. A charge per CD could be added onto the membership fees and would incur a small profit – this could be available during 2006. A master CD by SNAP printers could be available for burning further CD copies – the commercial production option was preferred. Proposal approved.

4.4 New Zealand account status: NZ$2,800. The software update can be paid for from this account.

4.5 Outstanding contributions to the Journal are required urgently.

5 Education Officer’s report

5.1 No new diplomas have been awarded.

6 Correspondence

6.1 Letter received from ANZCA SIG requesting that an ANZCA SIG member sits on the SPUMS Education Board for authorisation of the SPUMS Diploma – for Special Interest Group members of ANZCA. The request was endorsed by the majority of the Committee.

7 Other business

7.1 The Committee were informed that the current Treasurer had advised his desire to resign from the position on completion of this calendar year. The Committee would prefer that he remain in this position but wish him well in his future endeavours if he is unable to remain. Successor is yet to be determined. With respect to Dr Patterson’s current role in acting as Convenor of the 2006 ASM, he also advised that he would be happy to hand over that task if the Committee can find someone to assume this role.

7.2 Australian Standards Report: Dr Smart reported on the proceedings of the recent AS meetings. This report is included as an annex to these minutes.

7.3 ANZHMG phone conferences (one per year) agreed to be paid for by SPUMS.

7.4 HTNA prize dually awarded to Helen Mullins from Fremantle: A review of visual acuity changes in patients receiving more than 20 treatments; Anne Sydes from Wesley: A case series of pyoderma gangrenosum.

7.5 Congratulations extended to Des Gorman who has recently accepted the appointment as Head of School of Medicine at the University of Auckland.

Closed: 1052 hr

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

<www.hboevidence.com>
Combined meeting of Australian Standards SF017 Occupational Diving and CS083 Recreational Diving

Held on Monday 19 September 2005

A combined meeting was held at Australian Standards in Sydney to discuss a number of International Standards drafts which have been proposed from the International Standards Organisation (ISO) covering the health and training of recreational divers at the following levels:

1. Supervised diver – to 12 metres
2. Autonomous diver
3. Dive leader (divemaster)
4. Instructor level 1 (Assistant instructor)
5. Instructor
6. A broader standard covering providers of training

The Australian equivalent is the recreational 4005 series.

The ISO standards cover terms and definitions, competencies, prerequisites, theoretical knowledge, personal and specific scuba skills and assessment of the recreational divers. The standards also were very light on defining the amount of theory required. Surprisingly these standards did not even define that they were designed to train people on air.

The International Standards presented to the Committee were significantly lacking in detail and inconsistent regarding the need for diving medicals prior to undertaking a course. For example there were three different wordings regarding health requirements with the lowest standards applicable for entry-level divers. The following are quoted from the draft standards:

Supervised Diver and Autonomous Diver: “Documented evidence shall be obtained that the student has been medically screened as suitable for recreational diving by means of an appropriate questionnaire or medical examination. In case of any doubt or at the scuba instructor’s discretion, students shall be referred to proper medical resources. If the student is not examined by a physician the student shall be obliged to confirm by signature that he or she has understood the written information given by the scuba instructor on diseases and physical conditions which may pose diving related risks.”

Dive Leader (divemaster): “Documented evidence shall be obtained that the student has been medically screened as suitable for recreational diving. NOTE In some countries and training organisations a medical examination is mandatory.”

Scuba instructors level 1 and 2: “Scuba instructor candidates shall be medically screened as suitable for diving according to procedures laid down by a competent medical authority. If such procedures are not specified scuba instructor candidates shall provide evidence of a diver medical examination not older than one year unless the medical doctor who has carried out the examination specifies longer validity.”

After working through the documents word by word, the CS083 Australian Committee rejected the documents, with a detailed submission forwarded to ISO. The ISO standards fell far short of the existing 4005 series Australian Standards in their detail relating to definitions, emergency equipment and procedures, risk assessment, and the standards of supervision required for the divers. The Committee’s position was that all divers covered by the standards required diving medicals.

There are some interesting processes taking place in relation to the International Standards. The ISO series we examined evolved from the European Standards Committee, with some origins from the tourism and leisure sector. There is also an attempt to fast-track the ISO standards. There also appears to be some pressure on Australian Standards as an organisation to adopt international standards, even when our own standards have greater detail and have been more thoroughly worked.

Australia is only a single voting member in a larger body containing over 20 countries. It is likely that, although our objections to the ISO documents will be heard, we will be unable to influence the final ISO standards published. Once ISO standards are published there is likely to be political pressure for Australia to adopt them because they cover areas in common with Australian Standards such as the 4005 series. The only option we have if ISO does not listen to our input, will be to provide appendices and additions to the standards to suit the Australian conditions.

It is of note that the AS2299.3 covering professionals working in the recreational industry did not have an International Standards equivalent and the detail covered in this standard is far in excess of the detail covered in the International Standard No.6.

Overall, I have significant concerns about the International Standards process allowing adequate Australian input given our substantial experience in recreational diving in this country.

Dr David Smart
SPUMS Representative, Australian Standards (Occupational)
Standards Australia Meeting SF017

Held on Tuesday 20 September 2005

Topics discussed
Revision of Australian Standard 2299.1 Occupational Diving Standard Occupational Practice
Review of draft 2815.5 Training and Certification of Occupational Divers Part 5 Dive Supervisor

The main areas covered under the Occupational Diving Operations were:

1. Recompression chamber support:
   In the absence of clear evidence outlining how recompression chamber support should be provided to the on-shore and off-shore industries as well as scientific diving, an expert consensus was agreed to. The situations for commercial diving requiring a chamber within two hours were defined. A second time period greater than two hours for chamber support was defined with some restrictions on diving practices apply. This simplified the Standard from 3 columns to 2 in relation to chamber support. The scientific diving community was also provided with risk assessment guidelines which would define the situation where scientific diving required a chamber in less than two hours, for example: risk of entanglement, use of specialised tools, decompression diving, diving greater than 30 metres and risk of rapid ascents. A detailed risk assessment form was also developed for assessing risk in relation to diving in accordance with AS2299.1. The medical fitness to dive form has been slightly revamped but would not be significantly different from the existing 2299 form.

2. The AS2299.1 (2005) form will also be released for public comment, probably at the end of the year.

3. This meeting also reported that the AS2299.4 has been released as an official standard and is available to the public for purchase. This covers film and photographic diving.

4. Review of the Training and Certification of Occupational Divers Part 5 Dive Supervisor:
   This occurred at the meeting and a consensus was agreed to allow this form to be released for public document and public comment.

Future business of the Committee will require a review of the AS2815.1.2.3.4 series and a further review of the Scientific Standard 2299.2.

Dr David Smart
SPUMS Representative, Australian Standards (Occupational)

SPUMS Annual General Meeting 2006

Notice of the Annual General Meeting of SPUMS to be held at The Pearl South Pacific Resort, Pacific Harbour, Fiji, at 1800 hrs, Wednesday 7 June 2006

Agenda

Apologies:
Minutes of the previous meeting:
Unratified minutes of the previous meeting will be posted on the meeting notice board and appeared in the SPUMS J. 2005; 35: 97-101.

Matters arising from the minutes:
Annual reports:
President’s Report.
Secretary’s Report
Education Officer’s Report
Presidents’ Committee Report

Annual Financial Statement and Treasurer’s Report:
Proposal regarding subscription fees for 2006:
That the annual subscription rates for membership of the Society be set at AUD130.00 plus GST for Full Members and AUD70.00 plus GST for Associate Members with effect from January 2007.

Proposed: Dr A Patterson; Seconded: Dr C Acott

Reasons:
Rising costs of running the Society and producing its Journal make the increase in subscription rates inevitable.
The subscription rates have been held at present levels for some four years, in the face of inexorable increases in costs.
The proposed new subscription rates reflect a very modest rise compared with CPI increases or inflation over the same period. I commend the new rates to members.

Election of office bearers:
Nominations have been called for the positions of Treasurer and one committee member.

Appointment of the Auditor:
Business of which notice has been given:
1. Motions re Consumer Affairs-required amendments to constitution to comply with Victorian State legislation.
   Proposed: Dr Williams Seconded: Dr Sharkey

2. Motion re adoption of model rules for publishing of Minutes
   Proposed: Dr Walker Seconded: Dr Sharkey

3. Motion re additional membership category for retired members
   Proposed: Dr Walker Seconded: Dr Sharkey

4. Nomination of Martin Sayer as Full Member
   Proposed: Dr Davis Seconded: Dr Acott
In their review article ‘Reverse dive profiles: the making of a myth’, Edmonds, McInnes, and Bennett conclude that the results of a workshop report revoke established procedures advocating forward dive profiles (FDPs) and promote reverse dive profiles (RDPs) as safe and equivalent alternatives. The authors have added little to the debate that took place at the Workshop. Four pages of criticism of an historical document supplemented by five paragraphs of “new data” fail to impose the desired level of uncertainty on the subject of RDPs, in the context of the Workshop’s findings and conclusion.

The original aims of the Reverse Dive Profile Workshop were to challenge the reasoning behind FDPs and to generate an understanding as to where the historical objection to RDPs originated. While there was a lack of definitive experimental evidence advocating RDPs, it was the lack of evidence prohibiting them that was the issue. In their review article ‘Reverse dive profiles: the making of a myth’, Edmonds, McInnes, and Bennett fail to impose the desired level of uncertainty on the subject of RDPs, in the context of the Workshop’s findings and conclusion, and have added little to the debate that took place at the Workshop. We find no reason for the diving communities to prohibit reverse dive profiles within the no-decompression limits for dives less than 40 msw (130 fsw) and depth differentials less than 12 msw (40 fsw).

The workshop data

While Edmonds et al point to the lack of definitive experimental evidence advocating RDPs, it is the lack of evidence prohibiting them that is the issue. Although we agree that RDPs have become more prevalent in recent years, the ability of divers to manage an acceptable probability of decompression sickness (pDCS) will clearly depend on the extent to which their profiles approximate the prescribed dive computer algorithms and concomitant decompression obligations. The rationale for the ban against RDPs reviewed at the Workshop indicated that it, also, was based on opinion (and theory) rather than evidence. In the absence of supporting evidence, the necessity of a ban was called into question. Forward profiles are not banned even though we know they have been reported to cause DCS.

Accepting the paucity of experimental data directly addressing the reverse profile issue, the Workshop also succeeded in demonstrating that the traditional recreational diving recommendation (deep then shallow) was similarly lacking in sufficient evidence to justify its abolition. We also showed that RDPs were included in the validation of several tables and dive computer algorithms. Edmonds et al appear to discount these historical data, preferring instead to assume that the safety of FDPs is now being revoked in favour of RDPs.

The scientific, commercial, and military operational diving profiles are well documented and an outcome is ascertained for each profile (DCS/no DCS). In that vein, we argue that these operational exposures in fact constitute data and are not opinion based. The scientific diving community’s diving data are scrutinized and recorded for US regulatory purposes by mandate of the Department of Labor. From 2000–2005, we have seen no increase in DCS cases from RDPs. Vann et al reviewed the Project Dive Exploration (PDE) data and found no evidence that RDPs had higher DCS risk than FDPs for diving as conducted by the PDE volunteers. Millions of dives are being done each year around the world and we have no idea what the predominant approach to diving is. FDPs may well be favoured due to the historical ban on RDPs. However, information from chamber operations shows that the predominant profiles of divers presenting are FDPs. The hypothesis that there exist
no physiological data prohibiting reverse profiles within the envelope of the Workshop’s conclusion stands. Operational data from the diving communities clearly show that FDPs were preferentially driven by logistical and mechanistic considerations for over a half century. Neither the US Navy nor commercial diving operational procedures specifically prohibit reverse profile diving.

The authors quote the Convenor as stating “Does it really matter in which order dives are conducted as long as one keeps track of nitrogen loads and performs adequate decompression?” They continue “The follow-up question that remained unanswered was: do RDPs and FDPs actually have the same decompression obligations, and can we therefore apply the same decompression requirements to them?” This is incorrect. They ignore what was stated about keeping track of nitrogen loads. On the contrary, FDPs and RDPs were repeatedly recognised as not requiring comparable decompression. Edmonds et al misinterpret our conclusion by testing “mirror” profiles, yet nowhere in the findings and conclusion, or in the body of the Proceedings, did we imply that RDPs that were mirror images of FDPs could be safely undertaken. This appears to be the tangent that the authors embarked on.

Edmonds et al have inserted into their argument observations by Huggins, who hinted at the potential for more severe DCS with RDPs from chamber treatment observations, and St Leger Dowse et al, who analysed UK female divers’ log books and indicated that symptom rates were higher in those using RDPs. These observations are valid, but in the context of the authors’ argument, they are not evidence. Their text suggests that these data support the notion that DCS severity and symptom rates are greater with RDPs. However, as they point out, neither data set reached statistical significance. The odds ratio for Huggins’ data was 1.21 (95% CI 0.68, 2.13), arguably not even close to statistical or clinical significance. Furthermore, there was insufficient detail in the data to control for dive profile, maximum dive depth, or any other risk factor.

Regarding the restrictions agreed upon at the Workshop, these were inserted into the conclusion in order to be conservative, and to obtain consensus (since not all participants opined that the RDP “ban” should be completely abolished). With the stipulations as stated, there was in fact 100% agreement (of 49 participants).

Indeed, Edmonds et al’s assertions represent exactly the kind of conclusion that can arise without historical perspective. Presented with the same literature we searched to examine the gradual evolution of the ban on reverse dive profiles, we are optimistic that the authors would similarly conclude that there exists a lack of definitive experimental evidence supporting this ban. However, diving operational history with RDPs can be neither ignored nor changed.

From the modelling perspective presented at the Workshop we remain convinced that it does not matter what the pattern of profile exposure is provided two things are taken care of: quality decompression according to the last exposure, and not unwittingly creating bubbles at an early stage, which are then ignored.

The animal experiments

Edmonds et al’s evidence for the making of a reverse-profile myth resides in a series of animal experiments. However, the myth-debunking extrapolation to humans, or to the Reverse Dive Profiles Workshop findings and conclusion, is inappropriate. As reported, this study’s results have no bearing on the real world of diving.

Dive severity can influence the conclusions of a study. The key question is when do the dive profiles become severe enough to show a significant difference between RDPs and FDPs? This question can be answered only by recording human dive profiles during field use and documenting the outcomes. Is it possible that the authors made up their minds about RDPs and constructed experiments to support their preconception? We agree that under some circumstances RDPs can be hazardous but that has yet to be demonstrated in humans. The inapplicability of their animal study to humans is the greatest weakness of their review article.

Many models will demonstrate that for the same dives, ‘deep’ followed by ‘shallow’ will produce higher tissue inert gas tensions, and will therefore require different decompression procedures. This is reflected in standard decompression algorithms, such as the US Navy Standard Air Decompression Tables. That mirror-image RDPs demand an equal decompression obligation to FDPs is argued by default and no cogent mechanistic explanation is offered by the authors for the experimental design of their animal dives. If they imply that RDPs in a repetitive series incur the same decompression obligation as FDPs, they must reconcile their scenario with the observation that there exists no dive computer algorithm or table that would allow such profiles without significantly altering the pDCS. The experiment designed by Edmonds et al to excommunicate the workshop findings does not take into account any type of handicap in repetitive diving. Both Huggins and Gerth and Thalmann estimated DCS risk on profiles within the algorithms’ required decompression parameters. For the repetitive dive scenario they took into account the handicap accumulated due to the previous dive (FDP or RDP). In order to maintain the same level of DCS risk in a repetitive dive, the current dive must be shorter, shallower, or start after a longer surface interval (SI).

A bubble model would prescribe the following if a diver intended to repeat a FDP series (30 msw/30 min, 15 min SI, 20 msw/30 min, 15 min SI, 10 msw/30 min) in reverse order. To keep the dive depths and bottom times constant, the surface intervals would have to be extended as follows:
These modifications would provide a predicted DCS risk that was approximately equal for FDPs and RDPs.

The authors state “our findings suggest that multi-level and repetitive dives performed in the established forward profile manner are less hazardous than those performed in the reverse profile mode.” However, to imply that a Haldanian-based dive computer will allow hazardous profiles is incorrect and misleading.

Edmonds et al successfully tested nitrogen levels at the surface following these four profiles:

- 36 msw/30 min to 24 msw/30 min to 12 msw/30 min
- 30 msw/40 min
- 30 msw/40 min, SI 15 min, 20 msw/40 min
- 30 msw/40 min, SI 15 min, 20 msw/40 min, SI 15 min, 10 msw/40 min

Using the maximum tested surface nitrogen loading for tissues with halftimes ranging from 5 to 480 minutes thus established, we have the following things to say about the profiles that proved hazardous:

- for the RDP multi-level dive that begins with 12 msw/30 min to 24 msw/30 min, no remaining time was allowed for a subsequent descent to 36 msw. The study’s results from 30 minutes at this depth causing 50% casualties come as not unexpected, and;
- for the RDP repetitive dive that consisted of 10 msw/40 min, SI for 15 min, 20 msw/40 min, SI for 15 min, then descent to 30 msw, only 19 min were allowed as compared to the tested 40 min that produced 33% DCS.

Thus, diving shallowest first (RDP) converts a FDP that barely requires decompression to a dive that requires much decompression, underscoring the ‘practical’ reasons divers perform FDPs. The question is whether the second dive, if proper decompression is executed, is as safe as the first dive. In this case, we would not want to venture a guess (i.e., a borderline ‘no-stop dive’ versus a properly executed decompression dive), but certainly to decompress the second (RDP) dive the same way as the first (i.e., ‘no stop’) is unsafe and not what the Workshop recommended.

Conclusion

We find no reason for the diving communities to prohibit reverse dive profiles within the no-decompression limits for dives less than 40 msw (130 fsw) and depth differentials less than 12 msw (40 fsw).

References

Drs Edmonds, McInnes and Bennett reply:

The response of Lang and Lehner to our article on “Reverse dive profiles: the making of a myth” is welcome, shedding more light as it does on the intended meaning of the Workshop recommendations.¹ We think their response makes it clear that we are in agreement about the facts. It is on the interpretation of these facts that we disagree, and the primary reason for our article was to illustrate, by documenting the statements of other delegates, that we are not alone in interpreting the final recommendations as contentious. We attempted to put the recommendations into perspective, highlighting the qualifications and doubts expressed in the proceedings of the Workshop.

Having organised and edited the Workshop, Lang and Lehner are in a position to appreciate the controversial nature of the problems of comparing the relative safety of forward dive profiles (FDP) with that of reverse dive profiles (RDP). They appreciate the limitations of the data, as described in their letter, but others who just read and accept the findings and recommendations of the Workshop may not. Interpreted literally, the recommendations indicate no increase in DCS with RDP compared to FDP, and that the no-decompression limits are the same. Lang and Lehner claim that it does not matter what the pattern of the profile is, as long as there is adequate decompression. We agree. It is axiomatic. If you decompress adequately, you are much less likely to get decompression sickness (DCS), irrespective of the profile, and without any qualification.

Our objections were not so much to the absence of evidence in either direction (safety of FDP vs RDP), but to the implication that the two dive profiles are equivalent. RDPs impose different decompression requirements than FDP dives. We have never proposed the prohibition of RDPs, only (like Lang and Lehner) the application of appropriate (and different) decompression. This difference in decompression obligation was unfortunately glossed over in the summarised findings and recommendations promulgated.

We believe this is the explanation for subsequent publicity in the diving literature, which we quote in our article and which uses the Workshop as authority, that dismisses the significant differences in decompression requirements between RDPs and FDPs. This interpretation is inadvertently encouraged by Lang and Lehner in their own summaries: “There is no convincing evidence that RDP within the no-decompression limits lead to a measurable increase in decompression sickness”.¹ There is in this statement an assumption that all readers will understand that a different (and unstated) decompression requirement will operate in the two situations. We are sure this was not an intentional omission, and that the workshop participants understood this assumption very well. Perhaps so well that it seemed to be stating the obvious and did not therefore require clear elucidation.

If the recommendations stipulated that FDPs and RDPs had different decompression obligations and that one cannot extrapolate from one to the other, there would have been no need for our article. Unfortunately the Workshop is now being quoted as indicating no difference between FDPs and RDPs.

We also agree that some decompression algorithms in dive computers attempt to make allowance for an added risk with RDPs. We just do not know which ones, if any, achieve this effectively. What is needed is good experimental research to investigate the safety of a variety of algorithms. Because of the nature of the problem, we believe this is only achievable through appropriate animal models. Such models are inevitably imperfect and require extrapolation to the human experience. They are, however, superior in some respects to anecdotal reports of human diving experience where the algorithm in use is only one of the variables influencing outcome. The best assessment of safety is likely to be a synthesis of both types of investigation.

Areas in which we must agree to disagree, and which we discuss in our paper, include the historical development of the FDP recommendations, the logistics of applying the 40 metres’ sea water (msw) maximum depth and 12 msw differential gradient as recommended, and the appropriateness of some of the data presented in the Workshop.

Lang and Lehner imply a plethora of new data on RDPs from scientific divers from 2000–2005, and the scrutinised monitoring of these with only a minor DCS risk. In fact, the 2005 article gives no data on RDPs and approximately two thirds of the scientific dives are at depths less than 9 msw.² The argument is a little circular. To support the Workshop’s recommendations for the relative safety of RDPs they refer to new scientific diver data and direct us to the SPUMS Journal article for the data.³ In this article there are no such RDP data and the Workshop is referenced.

We suggest another revised RDP recommendation, which complies with the data available both before and after the Workshop:

“RDPs have different decompression requirements to FDPs, and these requirements should be validated for both decompression tables and decompression computer algorithms before use.”

References


Letters to the Editor

Bearded ghouls and scientific meetings

Dear Editor,

With respect to Dr Harris’ article in the December issue,¹ the pain from the bearded ghoul’s sting appeared to be resistant to the use of hot water. I was wondering how hot the water was? My clinical experience with stings from similar fish (scorpion fish and stonefish) indicates that the temperature of the water is crucial – warm water produces no relief but hot water produces initial relief but the pain reappears as the temperature of the water decreases. However, I am the first to admit that our knowledge of the action of these venoms is only ‘the tip of the iceberg’ and perhaps some venoms are resistant to first-aid hot-water treatment.

I was interested in the use of a sural nerve block for pain relief. I have used this nerve block for pain relief in these injuries with great success. However, I have had to combine it with a tibial nerve block for full relief in what appears to be the area involved in the photograph; the medial side of the foot is supplied by both the sural and medial plantar (a branch of the tibial nerve) nerves, but it is a poor photograph.

Where Dr Harris’ thoughts² on the SPUMS AGM are concerned, I agree with the Editor’s reply. I note Dr Harris’ opinion is based on attendance at one meeting (in ‘statistical terms’ expressed as n = 1). The SPUMS Committee is trying to improve the ASM but we do need participation from members to submit presentations and attend. Perhaps we can look forward to seeing and hearing from Dr Harris at future ASMs. Past onshore meetings have not been successful but this will be tested again in the future.

Dr Christopher J Acott
President, SPUMS
E-mail: <cacott@optusnet.com.au>

References

¹ Harris R. A fishy tale from Port Vila (with a sting in the tail). SPUMS J. 2005; 35: 225.
² Harris R. Time to change the Annual Scientific Meetings (ASMs). SPUMS J. 2005; 35: 227.

Key words
Envenomation, marine animals, medical society, meetings, letters (to the Editor)

Maintenance of Professional Standards (MOPS)

Dear Editor,

The following MOPS points have just been approved by the Australian and New Zealand College of Anaesthetists:

The “Introductory Course in Diving and Hyperbaric Medicine” presently held at Prince of Wales Hospital, Sydney has been approved under Code 161, Category 4 (Learning Project) for 100 CME points. The approval number for this activity is 02116 and is ongoing.

Jan P Lehm, Department of Diving and Hyperbaric Medicine, Prince of Wales Hospital, Randwick, NSW 2031, Australia
E-mail: <lehmj@sesahs.nsw.gov.au>

Key words
Letters (to the Editor), meetings, MOPS
Dear Editor,

I read with appreciation David Elliott’s synopsis of our first report on this project. Three reports have now been compiled, which can be found on the Health and Safety Executive’s website, and I write to summarise our findings to date. We studied United Kingdom professional divers who had passed a fitness-to-dive medical before 1991. In the first report there were three main conclusions. The major factors affecting health-related quality of life were work-related accidents for both divers and the control group of offshore workers. There was a very high prevalence of noise-induced hearing loss (close to 50%) in both groups with a weak association with saturation diving in divers. Eighteen per cent of divers as opposed to 6% of control subjects reported cognitive complaint which was associated with work as a welder and diving experience. Cognitive complaint was associated with a moderate reduction in health-related quality of life of the same order of magnitude as that associated with loss of a spouse or divorce but there was no evidence that there was more work-related disability in divers.

A follow-up study considered welding fume as a possible causative factor for cognitive complaint and looked again at the data from the first study to determine possible causative factors. There was no relationship between exposure to welding fume and cognitive complaint in divers, implying that divers who weld are exposed to something else that increases risk of cognitive complaint.

In further analysis of the data from the initial study, it was clear that cognitive complaint was associated with experience of the oilfield diving techniques, saturation, mixed-gas bounce and surface-oxygen decompression diving in unadjusted models. When the analysis was adjusted for possible causative factors other than diving, however, only mixed-gas bounce remained associated with complaint. Other significant associations were with work as a welder, neurological decompression illness, more than one report of exposure to contaminated breathing gas and reported exposure to “a lot of petrochemical solvents or paints”.

The present picture regarding cognitive complaint in UK professional divers is of an effect associated with oilfield diving but not necessarily with the act of diving itself since, although there was an association with neurological decompression illness, there were more important relationships with reports of exposure to toxins at work. There was a robust relationship, however, with experience of mixed-gas bounce diving. Although this technique is infrequently used in industry, this does have implications for ‘techie’ divers and deep, mines-clearance divers.

A follow-up study is planned to look at progression and to try to get a quantitative estimate of toxin exposure, but it may well be that improved occupational hygiene in oilfield diving will be the most effective means of improving safety for the profession.

John AS Ross
Senior Lecturer and Consultant in Hyperbaric Medicine
University of Aberdeen College of Medicine and Life Sciences
E-mail: <j.a.ross@abdn.ac.uk>

References


Key words
Letters (to the Editor), diving at work, occupational diving, occupational health, health surveillance, hearing, psychology, performance
DVD review

The duty of care

Produced by PADI Asia Pacific, Training and Education Department, 2004
Far North Queensland Film Company
Length: 66 minutes
Price: AUD18.69
Available on request from PADI Asia Pacific
Website: <www.padi.com>

The duty of care is a sobering insight into a civil court case resulting from a hypothetical diving accident. In the accident, inexperienced diver “Mark” was undertaking his first deep dive on a PADI Advanced Open Water course. He experienced problems with excessive air consumption, which led to an out-of-air ascent and, ultimately, his death. Introduced by Richard Evans (Quality and Risk Management, PADI Asia Pacific), the court case provides an excellent forum to present the facts of the accident, and to examine the events before and after the diver’s death. A number of errors were highlighted that led to dive instructor “Roger” receiving a finding of negligence against him. The courtroom scene is given authenticity by contributions from magistrate Trevor Black and barrister Kevin Priestley, and by PADI staff who perform roles in the case.

Mark had limited diving experience before enrolling in the course. He had problems with his buoyancy on a navigation dive the day before the accident. This initial dive was not directly supervised by Roger, but instead supervision was delegated to “Jim”, a divemaster. Jim noted Mark’s problems but did not communicate these to Roger, and Roger did not specifically inquire about any difficulties with the students before embarking on the deep dive the next day.

Before the deep dive Mark said he was nervous, but was not fully interrogated by the instructor. During the descent, Mark had difficulty with ear clearing, contributing to a delayed ascent and increased air consumption. His instructor did not confirm that Mark was OK before completing the descent. The dive was planned for 28 metres but reached 32 metres; beyond the limit of the PADI standard. Air consumption was not checked in any of the students until it was discovered that Mark had 70 bar left in his cylinder.

At this point Roger delegated “Yuki” (another inexperienced student) to accompany Mark to the surface. The instructor did not accompany the divers during the ascent. They ascended away from the anchor line and during the ascent, Mark ran out of air, attempted unsuccessfully to buddy breathe with Yuki, and then made an uncontrolled ascent to the surface. He was unconscious, and then sank before the dive boat could rescue him.

The court found that Roger had a duty of care to Mark, and that he failed to properly supervise and monitor Mark’s dive. It also expressed concerns regarding Mark’s failure to follow PADI standards. A ruling of negligence followed.

Nearly half the DVD is devoted to commentary by experts, including Dr Simon Mitchell (Diving Medicine Specialist), Chris Coxon (Dive Safety Expert, Queensland), Sharon Daniels (Clinical Psychologist), Michael Gatehouse (Solicitor and Diving Litigation Specialist). They all make the point that it would have been easier to defend Roger had he followed the PADI standards. David Strike (author of Diving and the media) provides perspective and advice on how to deal with the media. A useful contribution is also made by insurance executive Rob Veal, who points out the need for insurance and the likely cost of this event if individuals are not insured. The expert commentary finishes with a description of the aftermath of a dive accident, demonstrating how stressful and protracted the process can be for those involved, and the impact on all concerned.

Overall the DVD is a quality production and is relevant to the Australasian situation. It provides a detailed insight into diving risk management using the practical example of a fatal diving accident. The DVD would be suitable for all industry participants who derive their income from instructing or leading dives, and should also be of interest to recreational divers in general, because it covers the responsibilities that buddies have towards each other.

David Smart, MD, FACEM, FIFEM, FACTM, FAICD, Dip DHM is Medical Co-director, Department of Diving and Hyperbaric Medicine, Royal Hobart Hospital

Key words
Video (and DVD) reviews, recreational diving, legal and insurance, PADI, general interest

Diving-related fatalities resource

The coronial documents relating to diving fatalities in Australian waters up to and including 1998 have been deposited by Dr Douglas Walker for safe keeping in the National Library of Australia, Canberra. Accession number for the collection is: MS ACC 03/38.

These documents have been the basis for the series of reports previously printed in this Journal as Project Stickybeak. They are available free of charge to bona fide researchers attending the library in person, subject to an agreement regarding anonymity.

It is hoped that other researchers will similarly securely deposit documents relating to diving incidents when they have no further immediate need of them. Such documents can contain data of great value for subsequent research.
INTERNATIONAL CONGRESS ON DIVING & HYPERBARIC MEDICINE, MUSCAT 2006
Hosted by the Royal Navy of Oman

Dates: 2 to 7 December 2006
Venue: Muscat, Oman

International Faculty: includes Professors David Elliott, Des Gorman and Richard Moon

The Sultanate of Oman lies at the crossroads of Africa, Europe and Asia. Muscat ‘06 is an opportunity to attend a congress of the highest quality and to visit an exotic country with a unique heritage, renowned for its hospitality and safety for you and your family.

The congress is accredited by the School of Medicine of the University of Auckland for the postgraduate programmes in diving and hyperbaric medicine.

For additional information:
Sultanate of Oman, Said Bin Sultan Naval Base, Medical Center, Royal Navy of Oman
PO Box: 839, Postal Code: 111 Muscat
Phone: +968-26-346832
Fax: +968-26-346367
E-mail: <drhassan@dhm.org.om>
Website: <www.dhm.org.om>

HYPERBARIC TECHNICIANS and NURSES ASSOCIATION
14th ANNUAL SCIENTIFIC MEETING
Hosted by the Townsville Hospital Hyperbaric Unit

Dates: 24 to 26 August 2006
Venue: Jupiters, Townsville

Registration/Enquiries:
<TSV-HTNA2006@health.qld.gov.au>
Phone: +61-(0)7-4796-2080
Fax: +61-(0)7-4796-2082

SPUMS Journal CD

The SPUMS Journal, volumes 1-30, is available on CD.

To read and print these documents Adobe Acrobat Reader (version 3 or later) is required. This may be downloaded free of charge from the Adobe web site <www.adobe.com>.

The CD is available to members for Aust $25 (incl. GST or overseas mailing). The cost to non-members and institutions is Aust $90 inclusive.

Cheques or money orders should be made payable to: ‘South Pacific Underwater Medicine Society’. Credit card facilities are not available for this.

Contact: Steve Goble, Administrative Officer
E-mail: <stevegoble@bigpond.com.au>
SPUMS ANNUAL SCIENTIFIC MEETING 2007
Preliminary Announcement

Dates: 16 to 22 April 2007
Venue: Oceans Resort, Tutukaka, Northland, New Zealand
Co-convenors: Mike Davis and Simon Mitchell

Guest Speaker
Dr Neal Pollock, Duke University

Theme
From mountain high to ocean deep
The physiological challenges of extreme environments

EUROPEAN UNDERWATER AND BAROMEDICAL SOCIETY
32nd Annual Scientific Meeting 2006

Dates: 23 to 26 August 2006
Venue: Radisson SAS Hotel Norge, Bergen, Norway
Scientific Secretary: Prof Einar Thorsen, Haukeland University Hospital, Bergen
For additional information contact:
FJELL OG FJORD KONFERANSER AS
E-mail: <silje@fjellogfjord-konferanser.no>
Website: <www.eubs.org>

UNDERSEA and HYPERBARIC MEDICAL SOCIETY
Annual Scientific Meeting 2006

Dates: 22 to 24 June 2006
Venue: Hilton in the Walt Disney World Resort
Orlando, Florida
For additional information:
Lisa Wasdin
c/o Undersea and Hyperbaric Medical Society
PO Box 1020, Dunkirk, Maryland 20754, USA
Phone: +1-410-257-6606 extn 104
Fax: +1-410-257-6617
E-mail: <lisa@uhms.org>

ANZ COLLEGE OF ANAESTHETISTS
ANNUAL SCIENTIFIC MEETING
Preliminary Notice

Date: 13 to 17 May 2006
Venue: Adelaide Convention Centre, South Australia
Hyperbaric Special Interest Group session
• Iatrogenic cerebral arterial gas embolism
• Cost analysis of HBOT

For further information contact:
Dr Margaret Walker <margaret.walker@dhhs.tas.gov.au>

ROYAL ADELAIDE HOSPITAL HYPERBARIC MEDICINE COURSES 2006
Medical Officers Course

June/July 2006
Basic 26/06/06 to 30/06/06
Advanced 03/07/06 to 07/07/06

October/November 2006
Basic 23/10/06 to 27/10/06
Advanced 30/10/06 to 03/11/06

DMT Full Course
October 2006 3 weeks, 9/10/06 to 27/10/06

DMT Refresher Course
To be announced

For further information or to enrol contact:
The Director, Hyperbaric Medicine Unit
Royal Adelaide Hospital, North Terrace
South Australia 5000 or
Phone: +61-(0)8-8222-5116
Fax: +61-(0)8-8232-4207
E-mail: <Lmirbel@mail.rah.sa.gov.au>

4TH KAROLINSKA POST GRADUATE COURSE IN CLINICAL HYPERBARIC OXYGEN THERAPY

Dates: 26 to 28 April 2006
Venue: Karolinska University Hospital, Stockholm, Sweden

Online information and registration: <http://www1.stocon.se/karolinskaHBO/9/34386.asp>

For additional information contact the Secretariat:
Stockholm Convention Bureau AB
Box 6911
SE-102 39 Stockholm, Sweden
Phone: +46-8-5465-1500
Fax: +46-8-5465-1599
E-mail: <confirmation@stocon.se>

DUIKMEDISCH CENTRUM
MEDICAL ASPECTS OF DIVING ACCIDENTS AND ILLNESSSES

Dates: 16 to 20 October 2006
Venue: Diving Medical Centre, Royal Netherlands Navy

For information contact::
Diving Medical Centre, Royal Netherlands Navy
PO Box 10.000,
1780 CA Den Helder, The Netherlands
Phone: +31-223-653214
Fax: +31-223-653148
E-mail: <mj.veen@mindef.nl>
Instructions to authors
(revised June 2005)

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, including SPUMS Diploma theses, will be subject to peer review. Accepted contributions will be subject to editing.

Contributions should be sent to:
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Private Bag 4710, Christchurch, New Zealand.
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Requirements for manuscripts
Documents should be submitted electronically on disk or as attachments to e-mail. The preferred format is Word 97 for Windows. Paper submissions will also 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 be subdivided into the following sections: an Abstract of no more than 250 words, Introduction, Methods, Results, Discussion, Acknowledgements and References. Acknowledgments should be brief. References should be in the format shown below. Legends for tables and figures should appear at the end of the text file after the references.

The text should be double-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. Measurements are to be in SI units (mmHg are acceptable for blood pressure measurements) and normal ranges should be included.

The preferred length for original articles is 3,000 words or less. Inclusion of more than five authors requires justification as does more than 30 references per major article. Case reports should not exceed 1,500 words, with a maximum of 10 references. Abstracts are also required for all case reports and review papers. Letters to the Editor should not exceed 500 words (including references, which should be limited to five per letter). Legends for figures and tables should generally be less than 40 words in length.

Illustrations, figures and tables should not be embedded in the wordprocessor document, only their position indicated. No captions or symbol definitions should appear in the body of the table or image. Tables are to be in Word for Windows, tab-separated text rather than using the columns/tables option or othersoftware and each saved as a separate file. They should be double-spaced and each in a separate file. No vertical or horizontal borders are to be used.

Illustrations and figures should be in separate files in TIFF or BMP format. Our firewall has a maximum size of 5 Mb for incoming files or messages with attachments.
Photographs should be glossy, black-and-white or colour. Posting high-quality hard copies of all illustrations is a sensible back-up for electronic files. Colour is available only when it is essential and may be at the authors’ expense. Indicate magnification for photomicrographs.

Abbreviations may be used once they have been shown in brackets after the complete expression, e.g., decompression illness (DCI) can thereafter be referred to as DCI.

References
The Journal reference style is the ‘Vancouver’ style (Uniform requirements for manuscripts submitted to biomedical journals, updated July 2003. Web site for details: <http://www.icmje.org/index.html>). In this system references appear in the text as superscript numbers at the end of the sentence and after the full stop.1,2 The references are numbered in order of quoting. Index Medicus abbreviations for journal names are to be used (<http://www.nlm.nih.gov/tds/serials/jmi.html>). Examples are given below:


There should be a space after the semi-colon and after the colon, and a full stop after the journal and the page numbers. Titles of quoted books and journals should be in italics. Accuracy of the references is the responsibility of authors.

Any manuscript not complying with these requirements will be returned to the author before it will be considered for publication in Diving and Hyperbaric Medicine.

Consent
Studies on human subjects must comply with the Helsinki Declaration of 1975 and those using animals must comply with National Health and Medical Research Council Guidelines or their equivalent. A statement affirming Ethics Committee (Institutional Review Board) approval should be included in the text. A copy of that approval should be available if requested.

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DIVER EMERGENCY SERVICES PHONE NUMBERS

AUSTRALIA
1-800-088-200 (in Australia)
+61-8-8212-9242 (International)
The toll-free number 1-800-088-200 can only be used in Australia

NEW ZEALAND
0800-4-DES111 or 09-445-8454 (in New Zealand)
+64-9-445-8454 (International)
The toll-free number 0800-4-DES111 can only be used in New Zealand

The DES numbers are generously supported by DAN-SEAP

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

Information may be sent (in confidence) to:
Dr D Walker
PO Box 120, Narrabeen, NSW 2101, Australia.

DIVING INCIDENT MONITORING STUDY (DIMS)
DIMS is an ongoing study of diving incidents. An incident is any error or occurrence which could, or did, reduce the safety margin for a diver on a particular dive. Please report 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.

Diving Incident Report Forms (Recreational or Cave and Technical)
can be downloaded from the DAN-SEAP website: <www.danseap.org>

They should be returned to:
DIMS, 30 Park Ave, Rosslyn Park, South Australia 5072, Australia.

PROJECT PROTEUS
This project is to establish a database of divers who dive or have dived with any medical contra-indications to diving. At present it is known that some asthmatics dive and that some insulin-dependent diabetics dive. What is not known is how many. How many with these conditions die is known. But how many dive safely with these conditions is not. Nor is the incidence of diving accidents in these groups known. This project is under the direction of Dr Douglas Walker and Dr Mike Bennett. The investigation has been approved by the Ethics Committee of the Prince of Wales Hospital, Randwick, approval number 01/047.

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

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

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