Diving and Hyperbaric Medicine

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

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Drugs from the sea – celebrating Darwin

Decompression sickness and osteonecrosis

The diving reflex and oxygen conservation

'Out-of-air' and uncontrolled ascents

Scuba divers' pulmonary oedema

Trouble with 'pee' valves

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PURPOSES OF THE SOCIETIES

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

DIVING and HYPERBARIC MEDICINE
The Journal of the South Pacific Underwater Medicine Society and the European Underwater and Baromedical Society

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Invited editorial

What if Darwin had been a diver?

Martin DJ Sayer

This issue of *Diving and hyperbaric medicine* carries the fascinating review by Newman *et al.* of therapeutic agents from the sea.[1] Quite rightly the authors place their subject into the context of 2009 being the 200th anniversary year of the birth of Charles Darwin and the 150th anniversary of the book *On the origin of species by means of natural selection;*[2] but what if Darwin had been a diver?

Firstly we must assume that Charles Darwin was not a diver. Search *On the origin of species* or Darwin's account of his voyage of the *Beagle*[3] and there is no mention of diving. His grandfather, Erasmus Darwin, worked with engineers, physicians and scientists who were involved in the fledgling diving industry of the late 1700s,[4] but the scientific possibilities of using this new technology obviously passed his grandson by and there is no record of diving equipment being on board the *Beagle.*

Given his fascination with biology and biodiversity, the inability to go underwater must have been incredibly frustrating for Darwin; especially as you consider that, previous to *On the origin of species*, Darwin's main scientific contribution had been the publication of the book, *The structure and distribution of coral reefs*.[5] Imagine how Darwin, possessing a highly inquisitive mind, must have felt as he travelled for weeks on the *Beagle* between countless untouched Pacific coral atolls in clear blue seas but without any means of getting underwater to view the life on them? *The structure and distribution of coral reefs* did, however, contain some observations that supported the idea that the Earth was not static but was filled with change. Darwin was fascinated by how coral atolls came to be. These atolls invariably rose from deep waters but were made from the skeletons of animals that could only survive in shallow water.[6] Darwin's theory was that they formed around basalt spikes, which had been forced upward in the water column by volcanic activity but later sank back into the Earth's crust leaving the distinctive central atoll lagoon. It would take over a century to prove his theory,[7] but his mind was already made up and what we now refer to as plate tectonics underwrote in part at least five of the 14 chapters of *On the origin of species*.

In *On the origin of species*, Darwin first observes how man, through processes such as domestication and selective breeding, had produced animals that were distant variants of their origins in only a few thousand years (e.g., the domestic dog coming from the wild wolf) and different species in decades (there were 15 designated species of dog in Darwin's childhood, but over 50 by the time *On the origin of species* had been published.[8] Darwin was aware that this had been achieved through selection and that man had accelerated the process by being able to be quite ruthless in that selection process. His main question from this observation was 'could nature be influencing variation through a similar process of selection?' and his main driver for this question was his fascination with the diversity of existence. However, increased diversity had to have its limits and selection could be affected by fitness. The process termed 'natural selection' by Darwin outlined how inherited differences in the ability to survive in conditions of limited or diminishing resources caused the species to evolve and vary. Darwin's theories of how changes in global stability could have affected geographical distribution added to the selection pressures. It was not just physical variation; Darwin also considered how behaviour could change within the process of natural selection. Darwin was, no doubt, aware of the controversy that would be caused by the publication of *On the origin of species* and he dedicated a significant part of the book to arguing against what he saw as the main criticisms of evolution as a theory and why he considered it to be fact. Sadly, 150 years later, the overwhelming scientific evidence that evolution accounts for the diversity of the world we live in is still not accepted by many, but, rather, attributed to fundamental creation.[9]

Evolution is a theory that provides the intellectual framework to describe organic diversity, change and fitness. So, could examples of this have contributed to *On the origin of species,* had we been able to give Darwin a scuba set all those years ago? I am sure that Darwin would have targeted his diving on the coral reefs because they held a special fascination for him. He would immediately have been struck by the huge biodiversity supported by the reefs. What evolutionary clues would have been living amongst the diversity? He may have examined the prawns, shrimps, crabs, lobsters and crayfish and observed that, even though they were distinctly different species, the body plan was exactly the same with identical arrangements of the segments and limbs but with different proportions, shapes and uses.[9] Darwin may well have concluded that these species had evolved from a smaller number of ancestral 'crab' species. He may have been attracted to the cleaning behaviours of wrasses and shrimps and used diving to separate the cleaners from their hosts to observe how both suffer as a result. His conclusion may have been that cleaning behaviour had evolved through a process of mutual dependence. Watching an angler fish luring its prey using a modified dorsal spine, Darwin may have pondered if the complexity of the spine had evolved through a process of selective breeding whereby mate selection is influenced by the 'beauty and size' of the lure.[9]

Battling with his own buoyancy control (because all great scientists are poor divers!), Darwin may have wondered how the thousands of fish in front of him were maintaining their buoyancy. Being careful to catch a bony (teleost) fish, Darwin could have dissected his specimen to reveal a gas-filled swim bladder. But more than this, he may have worked

out that the fish was able to regulate the amount of gas in the bladder, the bladder was a modification of part of the gut and, in some cases, it helped the fish to hear better underwater as well. While he was performing the dissection, it would have been a shame not to examine the basic physiology of the blood of the fish; he would have discovered that the plasma was a slightly diluted version of full seawater. A more detailed investigation of marine and freshwater animals would have shown him a trend whereby the more advanced the animal was in evolutionary terms, the further the ionic composition of its blood plasma was removed from that of seawater.[10] By maintaining and regulating its internal physiology, an animal will benefit as it will be more able to contend with environmental change.

Once fishes had more control of their physiology, then the next step may have been to leave water altogether. The movement from water to land would obviously have been a major evolutionary step, and Darwin may have been thinking about this as he surfaced from his dive and caught a glimpse of amphibious blennies 'walking' on the foreshore. After a few large rums that night on the *Beagle*, Darwin would doubtless have come up with theories as to why fish would leave water and what adaptations allowed them to do so.[11,12] But confusion could have set in on his next dive, when the turtles he had seen earlier laying eggs on the beach were now grazing underwater at depth. Surely this must be an example of land animals evolving back to an aquatic habit? He would no doubt have made similar conclusion about the mammals while watching a whale or dolphin swim by, although he may not have necessarily noticed that the nearest terrestrial family related to whales are the African *Hippopotamidae*. What would he have made of the sea snakes that have evolved the ability to excrete nitrogen across their skin to avoid getting the bends?

Being able to dive would have certainly added to Darwin's knowledge and wonderment of the natural environment. But what would he have thought about the divers themselves? Would they show any evolutionary trends with time? Putting aside the possibility of a slight shift in the sex ratio of the offspring from couples where at least the male is a diver, any evolutionary shift is unlikely as there are few associated selection pressures. It could happen though if, for example, human survival ever depended on having to eat a particular food which can be obtained only by freediving to depths greater than 20 m thirty or more times a day.

It is extremely disheartening to conclude that the main present-day association between Darwin and diving is with the awards that carry his name. It is only by dying in a spectacularly stupid way that a diver can advance the fitness of the human species in an evolutionary fashion by ensuring that their 'stupid genes' are not passed on to future generations.[13] It is only by getting a 'Darwin award' that a diver can truly contribute to evolutionary theory – perhaps this should be a consideration in any hyperbaric treatment algorithm?

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All of Darwin's original texts are available to download in text or pdf formats at *The complete works of Charles Darwin online* (<http://darwin-online.org.uk>).

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Key words
Editorials, biology, marine animals, general interest

The front page photo of a barrel sponge, *Xestospongia testudinaria,* was taken by Martin Sayer at Kimbe Bay, Papua New Guinea during the SPUMS 2008 ASM.

The President's pages

Peter Germonpré
President, EUBS

Dear friends and colleagues,

You are reading my first 'President's Column', so please bear with me if it is still a bit rusty or uneasy. I accepted the role of President two years ago when I was elected Vice-President (that's the way things go in EUBS…); still, I am honoured to have your confidence in this, and grateful to be of service to our Society.

Firstly a word of thanks to our now Past-President, Alf Brubakk. Alf has been a "Name" in diving medicine research for a long time. His contributions to, and influence upon, diving physiology have been huge. Some may (on occasions) dislike his 'no nonsense attitude' (Nordic, anyone?), but I for one have always appreciated his direct approach to problems, and his ingenuity in finding solutions. He will, of course, not retire from ExCom, and I know we will be able to count on him for a long time to come.

In Aberdeen, we also said goodbye to Maide Cimcit as Member-at-Large. She has served the Society well for three years, and gave us good and wise advice. Although she could not be present in Scotland, she will be more than present in 2010, as the Secretary General of our 2010 Istanbul Meeting.

With the addition of a new Vice-President (Tino Balestra) and a new Member-at-Large (Andreas Møllerløkken), I think we now have one of the youngest EUBS ExComs ever. Not too young, but still this may be a good thing, as we are enthusiastic (if maybe a bit naïve). On the other hand, we must be careful to respect (some) traditions and customs that make EUBS and its Annual Meetings what they are. Some of the 'modernising' has already taken place; we will propose more in the future.

One important change will relate to the work to further provide a solid evidence base to diving and hyperbaric medicine. Since 1994, the European hyperbaric community has formally recognised the urgent need to increase the clinical scientific proof that hyperbaric oxygen (HBO) 'works'. The call for high-level scientific evidence for the efficacy of HBO therapy has become louder and louder in recent years, and several Health Technology Assessment reports have pointed out that there is still depressingly few good randomised clinical trials (RCTs) to back up most of the indications that we have accepted and recommended in our Consensus Conferences and Reports. As a result, the usefulness of HBO is, once again, in question.

This is not a new phenomenon. Professor Boerema, organiser of the First International Conference on Hyperbaric Oxygen Therapy in 1963, stated "*I think it is one of our responsibilities … to prevent an unscientific development of hyperpressure therapy*"; Julius H Jacobson II added "*If this form of therapy is to achieve a worthwhile and lasting place in the medical armamentarium, it can only do so on a firm basis of accurate physiological data … obtained in experiments, as well controlled as clinical medicine will permit.*"[1]

However, this time more is at stake. The scarcity of high-grade evidence has now become a powerful tool for government and social security health policy makers to restrict funding for HBO therapy, and whatever finances was available to sustain quality HBO services will rapidly disappear as the global economic crisis lasts. After all, where better to save than on an 'unproven' treatment? We could, of course, continue to just argue that high-level evidence is not possible, due to ethical reasons, but these arguments are all too easily dismissed as excuses by those for whom it suits. Whatever official recognition is lost now will be hard to regain later. Therefore, this time, we cannot choose to ignore these criticisms.

We all know how hard it is to start (and, even harder, to complete) a good-quality, prospective, RCT in HBO. We are a small group, geographically separated, we treat relatively few patients and, because in many cases we are providing a 'complementary therapy', we have difficulties assuring uniform standards of care and (even medium-term) followup of our patients. Setting up and conducting clinical trials in these circumstances requires a high personal commitment which we are often unable to provide for precisely these same reasons: behold the vicious circle!

The results of well designed, well-controlled and representative experimental (animal) studies should, in fields like ours, definitely be more highly valued than they are today. After all, in order to clearly observe the effects of HBO, e.g., in chronic wound healing, would require an extremely large number of patients. Why? Because each patient is unique and basically incomparable to another patient; age, sex, cardiovascular, pulmonary, neurological, endocrinological, and oncologic status, as well as any drug treatment may influence the 'natural tendency' to heal. Even if we could match most of these factors and compose a matched control group to perform randomisation upon, we would face other major criticisms: either the oxygen delivery system would not be identical, or the 'standard treatment' would be slightly different, or the patient would not be randomised to 'sham' hyperbaric treatment (can someone please explain to me the placebo effect of sitting inside a pressure chamber at 114 kPa breathing air on the healing of a foot ulcer?), let alone be blinded to the treatment? Laboratory animal studies do not suffer from these hindrances; well-designed and executed, they can provide much of the RCT evidence we so desperately seek. However, we must take utmost care to interpret their results

cautiously and only extrapolate to humans if we know the animal model is representative. These studies can and do provide us with the basic knowledge to apply HBO with confidence to selected human patients, so, even if they are only 'Level V' evidence, I suggest that in the absence of higher evidence, they should be taken into consideration in systematic reviews and HTA reports.

On the other hand, we should not be afraid to repeatedly question our work and refrain from applying or prescribing HBO indiscriminately. For many of our indications, randomised clinical trials are possible, even if they require major personal effort and time. Multicentre collaboration is essential in the conduct of such trials, as it increases the number of patients and reduces bias. This requires a consensus in what we call 'HBO'. A quick survey within Europe reveals that there are over seven different HBO treatment protocols for routine use, none of which has been proven to be superior. If we cannot agree on a common HBO treatment protocol, we will never be considered plausible when reporting the results of our trials.

We all have a lot of work to do. On the EUBS website, you will find from now on a new section: *Research, courses and events*. It is a tool to facilitate your participation in the massive effort that is needed in order to counteract this negative spiral. With this Journal, we will provide you with high-quality reports and offer you the possibility to publish your own. By collaborating with ECHM, EBASS, DAN Europe, ANZHMG and DAN SEAP, and many more HBO and diving medicine-related organisations, we will provide the framework for a sustained research effort. The only thing we, the EUBS and SPUMS ExCom and the DHM editors, cannot do for you, is the research.

"*In God we trust; all the others must provide data*".

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Key words
Medical society, research, editorials, general interest

The Editor's offering

This is the eighth issue since SPUMS and EUBS joined forces at the start of 2008. Both society executives are currently taking stock of this two-year trial period and will soon make decisions regarding the Journal's future path. As Editor, these past two years have been very successful. We have established a truly international Editorial Board, who have been enthusiastic in their support; the number of manuscripts submitted has doubled compared to all previous years and *Diving and Hyperbaric Medicine* (DHM) is now indexed on SCIE, which will provide the Journal an Impact Factor. Despite the limitations of Impact Factors in judging the quality of journals, especially for small specialties such as diving and hyperbaric medicine, many institutions insist on their researchers publishing only in journals indexed on SCIE and/or MEDLINE. Application for MEDLINE citation was made earlier this year, and will be reviewed early in 2010. Without such indexing, DHM may have an uncertain future, given the changing nature of medical publishing.

The major challenge is ensuring that there is something for everyone, as our readership is very diverse and we have an educational role to meet, whilst at the same time providing an effective vehicle for original research. This may not have been entirely successful, as both societies have seen shrinkage in their membership over recent years. We receive little feedback from members about your Journal, so please give this some thought and write to let us know what you would like to see in the future. With the upgrading of both websites, next year there will be a Journal page. Again, we would value your ideas on what should be available here. We are not yet at the stage of considering full electronic publication; indeed there seems little desire for this amongst members – at the SPUMS ASM in a show of hands of an audience of about 50 registrants, only one member indicated they wanted only an electronic version.

Articles in this issue include breathhold diving (the diving reflex is oxygen-conserving in man and reproducible in the laboratory); a possible link between limb decompression sickness in recreational divers treated with short oxygen tables and dysbaric osteonecrosis (would these changes be present with longer initial treatments, as practised in the UK and Australasia?); the demographics of running out of air and rapid ascents (divers as potential candidates for Darwin awards?) and unpleasant and previously unreported complications of technical diving.

Chris Battershill, whom I met once as a young PhD student when I did his first diving medical clearance in Christchurch over 20 years ago, agreed back in early 2008 to write an article on drugs from the sea. He has been under very considerable work pressure at the Australian Institute of Marine Sciences, and I would like to acknowledge his commitment and that of his colleagues in the USA in providing for us this fascinating insight into the search for potential marine natural pharmaceuticals. It has been very satisfying to be able to celebrate Charles Darwin in the Journal in this way, combined with the guest editorial by one of the UK's leading marine biologists, Martin Sayer.

I wish you all the very best for 2010, and here's to our continued international cooperation!

Mike Davis

Original articles

Oxygen-conserving effect of the diving response in the immersed human

Robert de Bruijn, Matt Richardson and Erika Schagatay

Key words
Breath-hold diving, freediving, diving reflex, immersion, vasoconstriction, oxygen consumption

Abstract
(de Bruijn R, Richardson M, Schagatay E. Oxygen-conserving effect of the diving response in the immersed human. *Diving and Hyperbaric Medicine*. 2009;39(4):193-9.)
Introduction: The human cardiovascular diving response has been shown to have an oxygen-conserving effect during simulated breath-hold diving by apnoea with face immersion. However, it is not known if facial immersion enhances the response to the same extent as that in the diver with the body immersed and if this leads to oxygen conservation.
Methods: Seventeen subjects each completed a total of 12 apnoeas of fixed, near-maximal duration. Four series of three apnoeas were conducted: dry body with apnoea (DA), dry body with face-immersion apnoea (DFIA), immersed body with apnoea (IA), and immersed body with face-immersion apnoea (IFIA). Air and water temperatures were 23°C. Heart rate, skin blood flow, arterial blood pressure, arterial haemoglobin saturation, lung volume and end-tidal fractions of carbon dioxide and oxygen were recorded non-invasively.
Results: Face immersion led to a greater reduction in heart rate during apnoea, regardless of body immersion (DA–DFIA 9.3%, 95% confidence interval (CI) 3.54, 0.1; IF–IFIA 7.9%, 95% CI 4.8, 0.2). Both DFIA and DA resulted in skin vasoconstriction, which was more pronounced during DFIA (16%, 95% CI 8.4, 0.3). During body immersion, skin vasoconstriction was reduced considerably, and neither IA nor IFIA reduced blood flow further. Mean arterial pressure increased more in the immersed condition than on dry land. Arterial saturation remained higher after DFIA (0.4%, 95% CI 0.2, 0.01) and IFIA (0.4%, 95% CI 0.4, 0.01) series, suggesting an oxygen-conserving effect of the more powerful diving response associated with face immersion.
Conclusion: We conclude that the oxygen-conserving effect of the diving response in the immersed diver is the same as that observed in the dry, horizontal, simulated diving model.

Introduction

Breath-hold diving, from here on referred to as diving, leads to a series of cardiovascular adjustments called the 'diving response'. The most pronounced adjustments are bradycardia and selective peripheral vasoconstriction.[1,2] The neural stimuli initiating the diving response are derived both from the apnoea and from stimulation of facial cold-receptors, e.g., by immersion.[3,4] Most studies of human diving abilities and associated reflexes have been based on laboratory studies, allowing a controlled environment and advanced techniques. A model used by many laboratories to simulate diving is apnoea with face immersion.[4,5] Studies with the prone subject performing apnoeas with the face either immersed or in air, i.e., causing a more or less pronounced diving response, have revealed that the diving response has an apnoea-prolonging effect and that the arterial oxygen (O_2) store is conserved during apnoea both during rest and exercise.[6–8] Oxygen conservation results from a reduced blood flow in tissues tolerant to hypoxia and lower myocardial O_2 consumption during bradycardia and leads to a slower O_2 depletion in the lungs.[9–11]

The impact of face immersion depends on the temperature difference between the skin and the water.[5] In a natural diving situation, however, the diver's entire body is often constantly immersed in cool water, in addition to the face immersion occurring during the apnoeas. Comparisons of heart rate responses have been made between horizontal apnoeas in air and warm water at 34°C.[12,13] The freediver in temperate regions will likely be diving in waters of 20–25°C with the use of a wetsuit, and with the face uncovered. A cooling of the body will result in a cold-induced vasoconstriction, which may have a negative effect on the diving response and possibly abolish O_2 conservation. Sterba and Lundgren showed that, compared to breath-holding while sitting in air, simultaneous vertical body and face immersion in cold water (20°C) reduced breath-holding time considerably but was accompanied by a strong bradycardia, while breath-holding in warm water (35°C) lengthened the breath-holding time, but without bradycardia.[14] They explain these results by an increased metabolic rate and respiratory drive at 20°C due to chilling. Paulev showed that, during continuous body immersion, apnoea without facial immersion resulted in a bradycardia similar to that found while breath-holding with facial immersion with the body in air.[15] However, no direct comparison was allowed between the two stimuli in that study, as the constant body immersion was done in 22°C water, and facial immersion in 15°C water, a situation likely to induce a more powerful response.[5]

An interesting observation during apnoea and facial immersion in 10°C water, in combination with immersion of the forearm in 10°C water, was that the bradycardia from the diving response had priority over the tachycardic response induced from the arm chilling.[16] This speaks for a maintained response with body immersion. However, in an already cool environment with reduced facial temperature, the effects of facial immersion may be reduced, decreasing the response magnitude.[5] Ferrigno and associates observed a diving response during immersion and exposure to increased ambient pressure, but its magnitude was not compared to the responses of the same individuals in air.[17]

Thus, it is not known to what extent O_2 conservation applies to the immersed diver. The present study, therefore, investigated the development of the diving response in the immersed human with and without facial immersion, with specific regard to its effect on O_2 conservation.

Methods

We compared the diving response during apnoeas (A) and face-immersion apnoeas (FIA) of the same duration, in horizontal dry-body (D) and immersed-body (I) conditions, respectively. A difference in arterial haemoglobin saturation after apnoea and face-immersion apnoea was used as an indication of O_2 conservation.

SUBJECTS

Seventeen healthy subjects (3 females and 14 males) volunteered for the study. Mean (SD) age was 28.7 (7.3) years, height 178.4 (7.7) cm, weight 77.4 (10) kg and mean standing vital capacity was 4.96 (0.9) L. Fourteen of the subjects had some prior experience in diving but no ongoing training, and three subjects practised diving regularly but with a maximum of two hours per week. Two subjects smoked occasionally and two were snuff tobacco users.

EXPERIMENTAL PROCEDURE

The study complies with the Helsinki Declaration and with Swedish laws and ethical standards. All subjects signed a consent form after being fully informed of the experimental protocol, which had been approved by the regional human research ethics board at Umeå University. To prevent excessive strain, the apnoeic duration was set for each subject at approximately 15 s less than their individual maximum breath-hold time, based on a single pre-trial maximal apnoea performed without hyperventilation or facial immersion. The short-term training effect observed when performing serial apnoeas, in combination with the time reduction by 15 s, would thus ensure that each subject could perform all apnoeas at the same, predetermined, fixed duration.[18] The average (SD) apnoeic time performed during the experiments was 58 (10) s. The experiments consisted of 12 apnoeas in total, divided in four different series of three successive apnoeas spaced two minutes apart. Body conditions were constant across each series, while facial immersion refers to apnoeic periods. These series were:

- Dry-body apnoea (DA)
- Dry-body face-immersion apnoea (DFIA)
- Immersed-body apnoea (IA)
- Immersed-body face-immersion apnoea (IFIA)

To minimize order effects, the conditions in the series were alternated and the starting situations were weighted between subjects. The choice was made to limit the alternating sequences to four, thus limiting the times a subject needed to change outfit. The four sequences used were as follows:

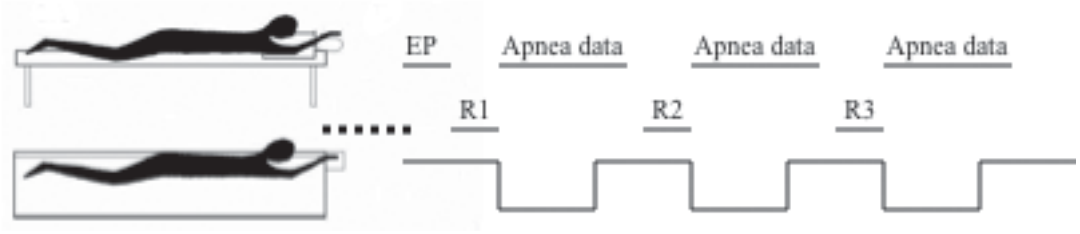
- DA, DFIA, IA, IFIA
- DFIA, DA, IFIA, IA
- IA, IFIA, DA, DFIA
- IFIA, IA, DFIA, DA

For the face and body immersions, mean (SD) water temperature was 23.1(0.4)°C, and the mean air temperature was 23.3(1.2)°C.

Vital capacity (VC) was measured in the standing subject at the start of all experimental sessions, in the prone position prior to the dry-body apnoeas, and in the immersed-body condition prior to the start of the immersed-body apnoeas.

In the dry-body series, subjects were outfitted with pneumatic chest bellows to detect respiratory movements and asked to

Figure 1
Position of the subject during apnoeas; dry body (top), immersed body (bottom); schematic shown of a series of three apnoeas with indications of different periods used for analyses (EP: effects of position; R1 – R3: reference periods for apnoeas 1 – 3); two-minute rest period between apnoeas



lie in a prone position on the bed with the head resting on a pillow on a board covering a small water container (Figure 1). In the immersed-body series, subjects wore 5 mm full wetsuits with the chest bellows placed on top. Once in a prone, floating position, a bar was placed across the tank in the water to support the legs, and a removable foam board supported the head of the subject between apnoeas. Probes for the pulse oximeter, photoplethysmometer and laser-Doppler flow meter were placed on the left hand, which was kept dry.

In all series the subjects relaxed for a minimum of 10 minutes prior to the beginning of each apnoea series. At two minutes before the first apnoea the data recording commenced and the subject was notified of the time remaining. At 30 s before each apnoea a nose clip was placed and with 10 s remaining a countdown began and the spirometer mouthpiece was offered to the subject, who continued to breathe normally and started the apnoea at the end of the countdown after a full exhalation followed by a deep, but not maximal, inhalation. The mouthpiece was removed during the apnoeas. Subjects were notified about the time at the half-apnoea point and by countdown for the last 10 s, and at apnoea termination they exhaled completely through the mouthpiece. Thus, recordings of inspired and expired lung volume, end-tidal fraction of oxygen ($F_{ET}O_2$) and end-tidal fraction of carbon dioxide ($F_{ET}CO_2$) were made. The face was dried immediately after each apnoea and the subject had a two-minute recovery period between apnoeas of a series. Recording continued throughout until two minutes after each third apnoea. At the end of the experiments, general comfort was evaluated for the dry- and the immersed-body conditions using a scale from 1 (very uncomfortable) to 10 (very comfortable) and a thermal comfort evaluation during immersion on a scale from 1 (very uncomfortable) to 10 (very comfortable) was made.

EQUIPMENT

VC, inspiratory (LV_{in}) and expiratory volumes (LV_{exp}) were measured using a spirometer (Vitalograph Compact II, Buckingham, England). A CO_2/O_2 analyser (Normocap Oxy, Datex Ohmeda, Helsinki, Finland) was connected to the mouthpiece of the spirometer to measure pre- and post-apnoeic end-tidal CO_2 and O_2. Heart rate (HR) and arterial oxygen saturation (S_aO_2) were measured continuously, with the averaging function set on 6 s, via pulse oximetry (Biox 3700e, Ohmeda, Madison, USA). Mean arterial pressure (MAP) was measured using an automated finger photoplethysmometer (Finapres 2300, Ohmeda, Madison, USA). Skin blood flow (SkBF) was measured using a laser-Doppler flow meter (Advance Laser Flowmeter 21, Advance Company, Japan). Respiratory movements were registered with laboratory-developed pneumatic chest bellows connected to a pressure sensor. An analogue event marker marking the apnoeic time (from the last inspiration before to the start of the first expiration after the breath-hold), was stored together with other data using a data acquisition system (MP100A-CE, Biopac Systems Inc, USA).

DATA ANALYSIS

Subjects served as their own control. To study the effect of position, resting values were obtained from a 60 s period starting after 10 min in that position (Figure 1). Control values for HR, MAP, SkBF and S_aO_2 were obtained from the period 90–30 s before each apnoea. Continuous graphs for the period from 25 s before until 40 s after the apnoea were made for HR, MAP and S_aO_2 by re-sampling to obtain a mean value for every 5 s, and calculating relative changes from the control taken before each apnoea. For SkBF, continuous graphs of the absolute data were used, since control values were very different because of cold-induced

Table 1
Resting values (mean ± SD) of heart rate (HR), mean arterial blood pressure (MAP), skin blood flow (SkBF), arterial oxygen saturation (S_aO_2), end-tidal fraction of oxygen ($F_{ET}O_2$) and carbon dioxide ($F_{ET}CO_2$) for dry-body apnoea (DA), dry-body face-immersion apnoea (DFIA), immersed-body apnoea (IA) and immersed-body face-immersion apnoea (IFIA), and the pooled averages for the dry- and immersed-body conditions for 16 subjects
*** $P < 0.01$, † $P < 0.001$**

	HR	MAP	SkBF	S_aO_2	$F_{ET}O_2$ (%)		$F_{ET}CO_2$ (%)	
	(bpm)	(mmHg)	(ml·min^{-1}·100 g^{-1})	(%)	pre apnoea	post apnoea	pre apnoea	post apnoea
DA	69 ± 10	100 ± 14	5.8 ± 7	97.4 ± 1	16.2 ± 0.9	12.5 ± 1	5.0 ± 0.6	6.3 ± 0.4
DFIA	70 ± 8	103 ± 11	5.0 ± 8	97.6 ± 1	16.2 ± 0.9	12.4 ± 2	4.9 ± 0.6	6.3 ± 0.5
Δ DA-DFIA	-1.0 ± 2	-3.0 ± 1	0.9 ± 0.5	-0.2 ± 0.2	0.01 ± 0.1	0.1 ± 0.2	0.07 ± 0.07	-0.003 ± 0.06
IA	74 ± 10	96 ± 13	1.5 ± 3	97.9 ± 1	16.1 ± 0.9	10.7 ± 1.7	4.9 ± 0.6	6.6 ± 0.5
IFIA	75 ± 12	95 ± 14	1.9 ± 3	97.5 ± 2	15.8 ± 2.6	11.5 ± 1.8	5.0 ± 0.9	6.6 ± 0.5
Δ IA-IFIA	-0.6 ± 2	0.9 ± 4.1	-0.4 ± 0.5	0.5 ± 0.4	0.4 ± 0.3	-0.7 ± 0.2†	-0.12 ± 0.09	-0.02 ± 0.04
Drybody	70 ± 9	101 ± 12	5.4 ± 7	97.5 ± 1	16.2 ± 0.9	12.4 ± 1.5	4.9 ± 0.6	6.3 ± 0.5
Immersed	74 ± 11	96 ± 13	1.7 ± 3	97.7 ± 1	15.9 ± 2	11.1 ± 1.8	5.0 ± 0.8	6.6 ± 0.5
Δ Dry-imm	-4.6 ± 2*	5.5 ± 4.5	3.7 ± 1.4†	-0.2 ± 0.3	0.2 ± 0.2	1.3 ± 0.3†	-0.02 ± 0.1	-0.3 ± 0.08†

vasoconstriction during immersion. To compensate for the difference in duration of apnoeas between subjects the first 30 s and the last 15 s of the apnoeas were aligned for HR, MAP and SkBF, and S_aO_2 was aligned with the end of the apnoeas. To determine if there were differences between HR, MAP, and SkBF measurements, the last 15 s of apnoeas were analysed. For determination of differences in S_aO_2 a 20 s period that encompassed the nadir was analysed.

STATISTICAL ANALYSIS

Data were further analysed for differences between DA versus DFIA, IA versus IFIA and the pooled dry versus immersed conditions, and these differences are given where appropriate, including 95% confidence intervals (CI). Comparisons between apnoea and face-immersion apnoea in both body conditions, and between the pooled values for dry-body and immersed-body conditions were also made using 2-sided paired Student *t*-tests. Significance was accepted at $P < 0.05$.

Results

Testing of one subject was terminated due to cold discomfort, and no results from this subject were included. No signs of shivering were observed in any of the remaining subjects. Some individual apnoeas were excluded from analysis because of obvious recording lapses, but calculations always

Figure 2
Mean (SEM) changes from reference in (A) heart rate (*n* = 15); (B) mean arterial pressure (*n* = 11); and (C) absolute values for skin blood flow (*n* = 14) for dry-body and immersed-body conditions, averaged over 5 s periods; vertical dashes indicate the beginning and end of apnoeas
■ apnoea in air; □ apnoea with face immersion; * $P < 0.001$

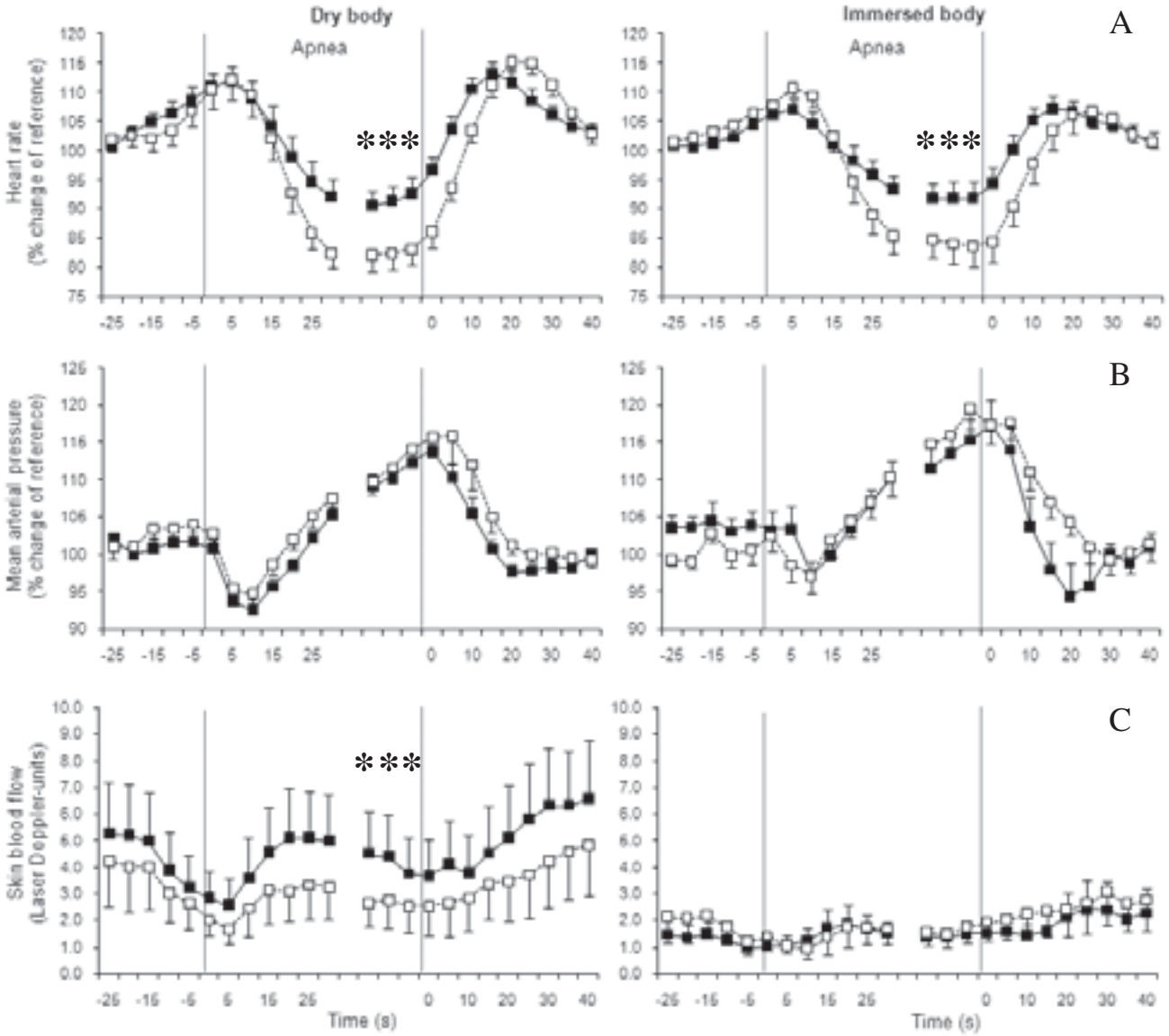
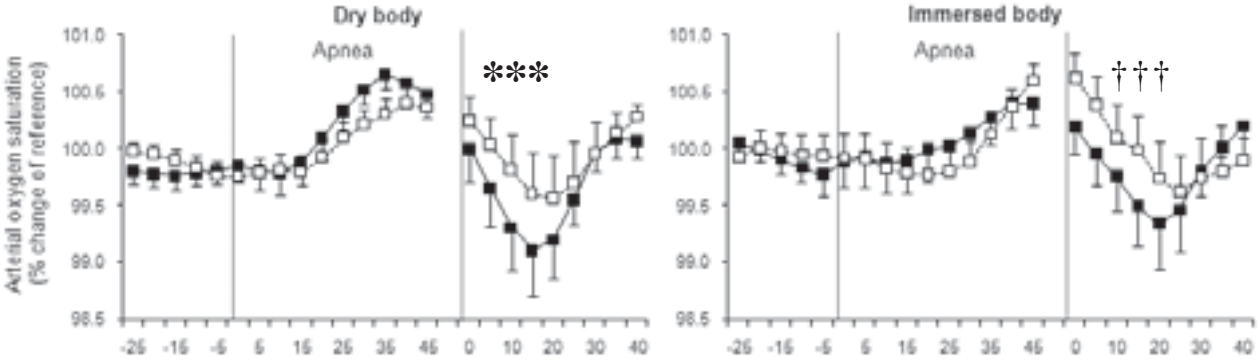


Figure 3
Mean (SEM) changes from reference in arterial oxygen saturation for 14 subjects for the dry-body and the immersed-body conditions, averaged over 5 s periods; the nadir corresponds with the end of the apnoea but is delayed due to circulation time; vertical dashes indicate the beginning and end of apnoeas; ■ apnoea in air; □ apnoea with face immersion; * *P* < 0.001; † *P* < 0.05



include at least two apnoeas per subject per series, as a basis for an individual mean. All subjects were able to perform their predetermined apnoea duration, except one who had some problems with the first apnoeas.

EFFECTS OF BODY IMMERSION

No differences in MAP or S_aO_2 were noted during any of the rest periods before the apnoeas, but HR was slightly elevated (4.6 bpm; 95% CI 3.5, 0.1; $P < 0.001$) and SkBF reduced (3.7 $ml.min^{-1}.100g^{-1}$; 95% CI 2.7, 0.09; $P < 0.001$) in the immersed-body condition (Table 1).

DIVING RESPONSE

The HR and MAP during apnoea showed similar patterns in all series. The bradycardia was more pronounced in the DFIA (18%) and IFIA (17%) series when compared to the DA (9%) and IA (9%) series (difference DA–DFIA 9.3%, 95% CI 3.5, 0.14; difference IA–IFIA 7.9%, 95% CI 4.8, 0.2; Figure 2A). The enhanced bradycardia during face immersion was consistent across the series of apnoeas in both the dry-body and immersed-body conditions. There were no differences in HR between the pooled dry-body and immersed-body series (-0.4%, 95% CI 3.2, 0.1). There were no differences in MAP between DA and DFIA (-1.6%, 95% CI 2.7, 0.1), or IA and IFIA (-3.7%, 95% CI 6.2, 0.2). However, the MAP increased more in the pooled, immersed-body series (6.8%, 95% CI 3.1, 0.1; Figure 2B). The SkBF patterns were similar in the dry-body series, but SkBF was reduced more in DFIA compared to DA (16.0%, 95% CI 8.4, 0.3). SkBF was lower in the immersed-body conditions compared to the dry-body conditions (-39.3%, 95% CI 28.2, 0.9; $P < 0.01$) and no differences in SkBF were found between IA and IFIA (2.7%, 95% CI 29.6, 0.9; Figure 2C).

ARTERIAL OXYGEN SATURATION

The more pronounced diving response during face immersion (Figure 2) was associated with less arterial desaturation, regardless of body immersion status (Figure 3). The S_aO_2 nadir, corresponding to the end of the apnoea, showed 50% less desaturation in DFIA compared to DA, and in IFIA compared to IA (absolute differences were -0.4%, 95% CI 0.2, 0.01 and -0.4%, 95% CI 0.4, 0.0 respectively; Figure 3).

RESPIRATORY PARAMETERS

The mean (± SD) VC for the prone position was 94 (4)% of the standing VC ($P < 0.001$) and, in the immersed position, it was 88 (6)% of the standing VC ($P < 0.001$); VC in the immersed position was 94 (7)% of that in the prone position ($P < 0.01$). There were no differences between series in LV_{in}, end-tidal fraction of O_2 ($F_{ET}O_2$) and end-tidal fraction of CO_2 ($F_{ET}CO_2$) at the last breath before apnoea. The relative inflation of the lungs was 61 (21) % in the dry-body condition and 64 (20)% in the immersed-body condition (Δ4.3%; 95% CI 4.9, 0.2; NS). At the end of the apnoea, there was no difference in LV_{exp} between all series, but differences were found in $F_{ET}O_2$ and $F_{ET}CO_2$. The $F_{ET}O_2$ was higher after IFIA compared to IA (Δ0.7%; 95% CI 0.4, 0.01; $P < 0.001$), while there were no differences between DFIA and DA, or in $F_{ET}CO_2$ (Table 1). In the pooled dry-body series, the $F_{ET}O_2$ was higher after apnoeas (Δ1.3%; 95% CI 0.5, 0.02; $P < 0.001$) while the $F_{ET}CO_2$ was lower compared to the pooled immersed-body series (Δ0.3%; 95% CI 0.16, 0.005; $P < 0.001$; Table 1).

COMFORT RATING

The subjects rated the immersed position in the tank less comfortable than the mean (SD) prone position on the

bed (6 (2) for tank and 8 (1) for bed; $P < 0.001$). Without the subject who interrupted tests due to cold discomfort, the group expressed no subjective cold problems (thermal confort mean score 8, range 5–10) despite the chilling effect on the skin evident from the reduced skin blood flow.

Discussion

From this study, one may conclude that face immersion during apnoea causes a more powerful diving response, reducing blood flow and O_2 consumption further compared to apnoea alone.[2,3] The results indicate that the diving response reduces oxygen consumption in the immersed diver in a similar manner to that in the dry, simulated diving model, which has not previously been shown. Even though both ambient and water temperature were 23°C, the diving response was more pronounced when apnoea was combined with face immersion, regardless of body immersion. This shows that the chilling effect of the water on the facial skin was sufficient to elicit a stronger diving response despite the strong pre-apnoeic vasoconstriction during body immersion. The enhanced diving response during face immersion was consistent throughout the series, showing that sufficient facial re-warming occurred in the two-minute intervals between apnoeas. For the diver, this suggests that it is important to expose the facial area involved in triggering the diving response for achieving maximal O_2 conservation. The main neural input from the face is through the ophthalmic branch of the trigeminal nerve, i.e., the forehead and eye region.[19] The face mask should, therefore, not cover all of this area (Figure 4). The slight increase in heart rate observed just before the apnoeas has been previously ascribed to an anticipatory response.[16] The initial increase in S_aO_2 during apnoea is related to the large inspiration.

The arterial haemoglobin desaturation was less pronounced during face immersion, in both dry- and immersed-body conditions, indicating that O_2 consumption was reduced by the increased diving response. This oxygen conservation would occur mainly via the following mechanisms:

- By reduced perfusion of organs that can withstand transient hypoxia by relying on anaerobic pathways, preserving most of the available oxygen for the use of the heart and brain;[1]
- By reduced myocardial O_2 demand through the reduction in HR, which further reduces oxygen usage;[9]
- The chilling of peripheral tissues may also in itself reduce local and thereby overall metabolism, as long as shivering is not induced.

While this study reveals an oxygen-conserving effect when apnoea is performed with the body immersed, thus adding body cooling and eliminating the effects of gravity compared to the dry model, it does not study the effects of pressure present during deep dives. It has been shown by earlier studies that cardiac performance during apnoeic exposure to increased ambient pressure at 20 metres' (m) depth is similar to that during apnoea at the surface.[17] Bradycardia was also shown to be similar during controlled dives in a diving tank at 10 m and 16 m depth.[20] Studies of the effects of lung volumes on the diving bradycardia show that the reduction in lung volume due to increased pressure at depth would likely enhance the diving response.[21] In addition, the diver in the field will in most situations encounter colder water when leaving the surface, which in turn should enhance the diving response.[5,22] Taken together, this supports the conclusion that the diving response conserves O_2 in the immersed diver to at least the same extent as in simulated dives, both during shallow and deep dives.

The reduction in SkBF before the apnoeas in the immersed-body condition, caused by strong vasoconstriction because of the chilling effect of the water, does not appear to have an effect on the magnitude of the overall diving response. Despite the constant low skin perfusion during body immersion, the blood pressure increased more during these apnoeas, compared to the dry-body condition, when normal skin perfusion periods preceded the apnoeas. This shows that other vascular beds, i.e., in the abdominal organs, may constrict more, and sufficiently compensate for the minor additional skin vasoconstriction during immersion, causing a similar effect on total peripheral resistance as during the non-immersed condition.

The resting HR in the immersed-body situation is slightly higher than in the dry-body situation, which may result from increased muscular tension due to cold and an increased effort from maintaining body position while floating. The latter explanation seems supported by the results from the questionnaire, which showed that subjects were less comfortable in the immersed situation due to factors not associated with chilling. This may also explain the differences between values in $F_{ET}O_2$ and $F_{ET}CO_2$ found after the apnoea, where increased muscular tension probably

Figure 4
A diver who exposes the facial area triggering the oxygen-conserving diving response (left) and a diver who covers all of the upper face with mask and hood (right), unlikely to benefit from the effect of chilling

caused an increase in O_2 usage and CO_2 production during body immersion. The increased metabolism does not seem to affect the extent of bradycardia during apnoea. This agrees with earlier findings of bradycardia during apnoeas with moderate exercise and swimming, reaching heart rates of at least as low levels as during inactive dives.[8,23]

Conclusions

Cold stimulation of the face plays an important role in the extent of the 'diving response' developed despite constant body immersion in cool water, and this leads to O_2 conservation in the diver. The oxygen-conserving effect of the diving response in the immersed diver is of the same magnitude as that observed in the dry, horizontal-body laboratory model used to simulate diving, which suggests that the simulated diving model is valid and can be used for further studies of diving-response functions in divers.

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Musculoskeletal decompression sickness and risk of dysbaric osteonecrosis in recreational divers

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Key words
Diving, decompression sickness, dysbaric osteonecrosis, magnetic resonance imaging (MRI)

Abstract
(Gempp E, Blatteau J-E, Simon O, Stephant E. Musculoskeletal decompression sickness and risk of dysbaric osteonecrosis in recreational divers. *Diving and Hyperbaric Medicine*. 2009;39(4):200-4.)
Introduction: Dysbaric osteonecrosis (DON) is a complication that usually occurs in professional divers or compressed-air workers. Its correlation with a previous musculoskeletal decompression injury (i.e., 'limb bend') remains a controversial subject. There is little information about the prevalence of DON and its relationship to decompression sickness (DCS) in recreational divers.
Methods: We undertook an observational, retrospective study of recreational divers treated for musculoskeletal DCS between 2004 and 2008 in three hyperbaric centres in the south of France using magnetic resonance imaging (MRI) following hyperbaric treatment.
Results: Twenty-five (11.5%) musculoskeletal DCS cases were identified amongst 288 diving accidents treated during this period. Average age was 38 years with a mean body mass index of 26 $kg.m^{-2}$. Joint pains were located in the shoulder area in 21 divers, mainly in experienced male divers after performing repetitive long, deep dives with adequate decompression using dive computers. Twenty-one of 25 injured divers were examined by MRI of the affected area shortly after the accident. Six had initial humeral lesions compatible with ischaemic necrosis, but in two repeat MRI examinations at three months did not reveal bone abnormalities. Increasing pain during hyperbaric treatment appeared to be the only factor associated with DON occurrence.
Conclusions: Musculoskeletal DCS in recreational diving is particularly seen in provocative dive profiles considered to carry a high risk for bubble production during decompression. The occurrence of this insult appears also to be related to other factors needing further study. The risk of early development of DON should not be ignored.

Introduction

The reported prevalence of musculoskeletal decompression sickness (DCS) or 'limb bends' (previously, type 1 DCS) in scuba divers varies from 3 to 31%,[1–3] mainly because of the different diving populations examined (recreational, commercial or military divers) or the decompression procedure used (computer-generated versus decompression table). Dysbaric osteonecrosis (DON) is a potentially disabling condition resulting in osteoarthritic changes when bone necrosis is juxta-articular. This pathological event usually occurs in professional divers or compressed-air workers exposed to iterative high ambient pressure, but has also been reported to appear in recreational scuba divers.[4,5] It has been reported that diving could lead to deterioration in pre-existing DON lesions, thus requiring that divers who have DON should be followed up frequently or excluded from diving.[6] In certain circumstances, DON may be considered as a late manifestation of a previous musculoskeletal DCS injury. However, despite the observed link between the two illnesses, their correlation remains controversial.[7–11] There is a general consensus that gas bubble formation during decompression is the primary cause of DCS and DON. Most hypotheses focus on an autochthonous bubble mechanism but there is no agreement on the actual site as far as DCS development is concerned, and it is unclear where, or how, bubbles form in the bone marrow cavity causing DON.

Magnetic resonance imaging (MRI) is a highly sensitive technique to detect early signs of DON.[12,13] However, there are no pathognomonic MRI findings specific to DON compared to osteonecrosis by other mechanisms. This technique can be used to demonstrate bone marrow oedema on fat-suppressed T2-weighted images and, subsequently, the classic necrotic area delineated by a hypointense signal line on T1- and T2-weighted sequences as described by Mitchell et al.[14] These imaging examinations have great prognostic value in determining whether the spherical shape will collapse or not.

To date, there are no data on the prevalence of DON after development of musculoskeletal DCS in recreational divers. This study was designed to determine the main predisposing factors of bends occurrence in this population and the proportion of DON after hyperbaric treatment by use of MRI of the affected site.

Materials and methods

We reviewed the clinical and diving data on scuba divers presenting between November 2004 and October 2008 with symptoms indicative of musculoskeletal DCS in three hyperbaric centres in the south of France (two in Toulon and one in Nice). Information obtained from the medical records included anthropometric data, history of previous

musculoskeletal DCS, diving experience (number of dives), parameters of diving exposure (maximum depth, total dive time and decompression schedule), delay from surfacing to first symptom occurrence, time to recompression and resolution or worsening of pain during hyperbaric treatment. A questionnaire was also used to define past medical history, alcohol and drug consumption. The study was approved by the hospital ethics committee.

The clinical diagnosis of musculoskeletal DCS was made when the criteria of joint pain, accompanied by myalgia and numbness, were recognized after the diver surfaced. Divers with symptoms suggesting neurological DCS (e.g., paraesthesia, motor impairment) were excluded after careful examination by the duty diving physician.

The follow up of injured divers was routinely performed by initial MRI of the affected site between one and 30 days after the insult, except in five divers who were not investigated until between four weeks and three months after the insult. Repeat MRI was performed between three and four months in divers in whom abnormalities were detected on the first MRI sequences. MRI examinations were performed on 1.5-Tesla MR units and consisted of T1- and T2-weighted images in the coronal and sagittal planes. MR images were evaluated initially by several radiologists from different imaging departments but subsequently reviewed by one of the authors (ES) trained in reading bone MRI. Imaging criteria to identify DON development at different stages were based on the staging system described by Mitchell et al.[14]

Although the data analysis planned was mainly descriptive, a stepwise multiple regression analysis was used to identify potential predictors of DON. Additional analysis to compare time to treatment between injured divers with and without bone lesions was performed using the Mann Whitney U test. A value of $P < 0.05$ was considered significant. Calculations were computed using Sigmastat 3.0 software program (SYSTAT Inc., Richmond, CA). All parametric data are presented as mean ± SD and non-parametric data as median and range.

Results

Twenty-five (11.5%) cases of musculoskeletal DCS were reported amongst 288 injured divers (58% neurological DCI, 21.2% inner ear DCS and 13.2% miscellaneous presentations) treated during the study period. However, only 21 divers (20 men and one woman) were retained for analysis after MRI examination (four patients missed). Age was 38 ± 8.4 years and BMI 26 ± 3 kg.m^2. Five of these divers had a history of previous limb bends. Close questioning did not reveal other identified causes of aseptic bone necrosis (e.g., trauma, coagulopathy, corticosteroids, alcoholism).

Diving profiles were as follows: maximum depth 45 ± 18 metres' sea water and bottom time 40 ± 16 min. A repetitive dive was recorded in 10 cases and no diver performed an inadequate decompression procedure (i.e., fast ascent or omitted decompression stops according to their dive computers). Physical exercise with excessive use of limbs was observed in only two divers. The breathing mixture was air except for one case where trimix (nitrogen 41%, helium 41% and oxygen 18%) was used.

The most frequently affected site was the shoulder (18 out of 21 divers) and both sides were equally affected (ten left versus eight right). Two limb bends were located in the elbow and one case involved the ankle. The median time from surfacing to the onset of initial symptoms was 10 min (range 5–600 min), and the median delay to recompression was seven hours (range 2–40 h). All patients underwent a single hyperbaric oxygen treatment (100% oxygen breathing at 253 or 283 kPa for 70–150 min), and no extensions or repeat treatments were given. Pain was usually fully relieved at the end of the treatment, but in seven divers the symptoms increased during recompression and continued to exacerbate while at depth, requiring intravenous therapy with non-steroidal anti-inflammatories. It is important to state that each of them was recompressed with a therapeutic table using 100% oxygen at 283 kPa for 150 min, equivalent to USN table 5, according to the general recommendations.[15]

MRI evaluation revealed a total of six out of 21 divers with juxta-articular humeral lesions consistent with DON in the same area as joint pain had occurred. Of these, two divers

Figure 1
T1-weighted coronal image from MRI at three months shows humeral diaphysal serpiginous lines specific to ischaemic necrosis

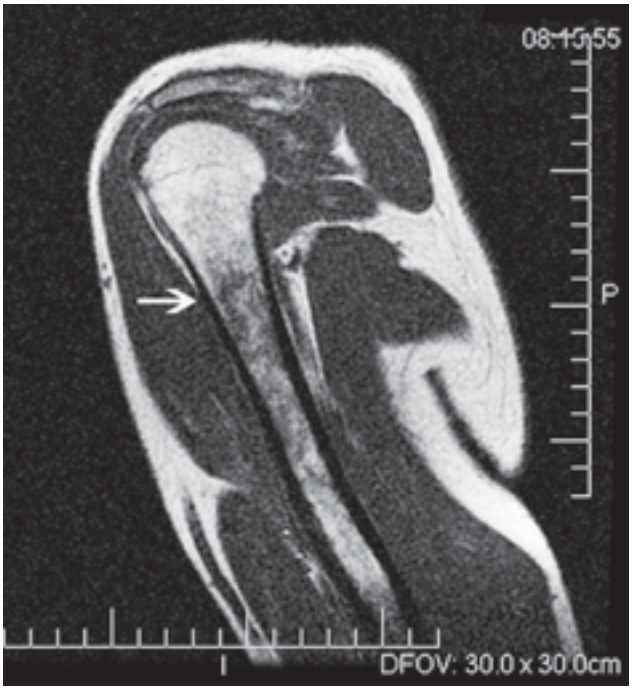
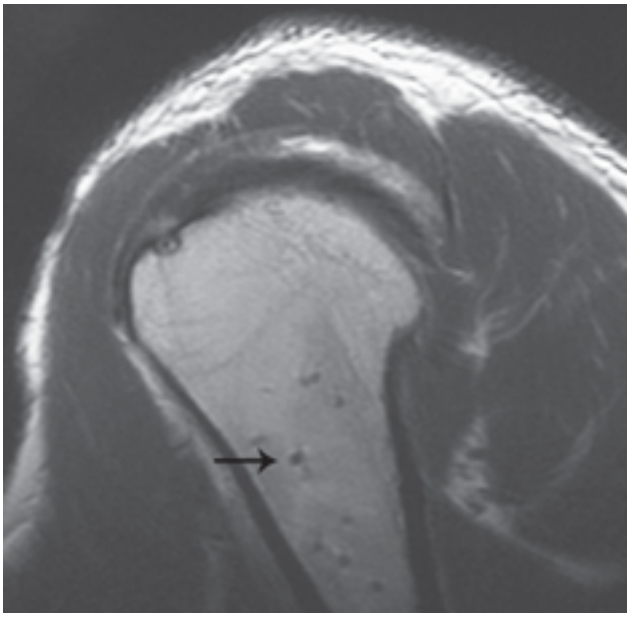


Table 1
Analysis of MRI outcome in 21 divers with musculoskeletal DCS according to diving data, clinical characteristics and time to recompression; MRI + indicates the presence of dysbaric osteonecrosis lesions; OR (95% CI) – odds ratio and 95% confidence intervals

Variable	MRI +	MRI -	*P* value	OR (95% CI)
Age (yr)				
≤ 40	1	9	0.15	7.5
> 40	5	6		(0.7,81.2)
BMI (kg.m^{-2})				
≤ 27	4	12	0.60	2
> 27	2	3		(0.2,16.6)
Diving experience (no of dives)				
≤ 200	1	2	1	1.3
> 200	5	13		(0.1,17.3)
History of DCS				
yes	2	3	0.60	2
no	4	12		(0.2,16.6)
Dive time (min)				
≤ 40	2	9	0.36	3
> 40	4	6		(0.4,21.8)
Depth (msw)				
≤ 45	4	8	0.66	1.7
> 45	2	7		(0.2,12.6)
Repetitive dive				
yes	3	7	1	1.1
no	3	8		(0.1,7.6)
Delay to onset of symptoms (min)				
≤ 30	4	9	1	1.3
> 30	2	6		(0.2,9.7)
Delay to treatment (h)				
≤ 6	1	9	0.15	7.5
> 6	5	6		(0.7,81.2)
Paradoxical pain				
yes	6	1	< 0.001	NA
no	0	14		

had MRI features of advanced metaphysal and diaphysal ischaemic necrosis (two and three months after the insult, respectively) while the four other cases presented findings suggesting bone marrow oedema on MR images initially performed between 24 h and 3 days following the accident. In the latter cases, when re-examined 3–4 months thereafter, the MRI scans showed significant metaphysal and diaphysal bone infarction concordant with definite lesions in two divers while the initial abnormalities detected in the remaining two divers had disappeared. Two example MRI slices with diaphyseal anomalies are shown in Figures 1 and 2.

Figure 2
T2-weighted sagittal image revealing multiple unexpected hypo-intense spots in the humeral marrow strongly evocative of bubbles (MRI examination 24 hrs following DCS)



Results of univariate analysis are presented in Table 1. Paradoxical pain, which continues to increase while at depth, was found to be the only significant variable associated with the development of ischaemic lesions seen on MRI ($P < 0.001$), and remained the only independent variable on multivariate analysis ($P < 0.001$). Moreover, the delay between onset of symptoms and hyperbaric treatment was not statistically different in divers without DON (median, 4.5 hrs) when compared with divers with DON (median, 8.0 hrs) ($P = 0.13$).

Discussion

The 11.5% prevalence of limb bends in divers presenting with DCS in the south of France is lower than epidemiological data from DAN reports.[2] The main reason is that DAN findings are not drawn from the treating diving physician but are completed by the patient or a health care professional after the DCS event, thus limiting the accuracy of recorded manifestations in this database.

Our results show that musculoskeletal DCS affected mainly experienced, male divers after performing repetitive, long, deep dives with adequate decompression schedule using dive computers. Occurrence did not appear to be related to some individual factors such as excess weight. However, it is noteworthy that the intensity of physical exercise on the bottom, that was previously thought to be a risk factor for DCS development, was uncommon in this study.[16] Similar

results were also demonstrated in a report of 58 recreational divers with DCS.[17]

The distribution of pain indicates that, in almost all cases, the shoulder was the predominant site, as already observed in bounce diving.[17] This difference from compressed-air workers or saturation divers, who experience a higher proportion of musculoskeletal DCS in the lower limbs,[18] has no obvious explanation. One possibility is the gravitational force between the upper and lower extremities, which causes pooling of blood at the bottom (and consequently alters blood circulation and nitrogen elimination), in the case of dry dives or when workers spend longer hours working in a standing position. The symptom latency after dive completion shows that bends presented soon after surfacing (60% within 30 min), but with onset being reported 12 hours after the dive in three cases, supporting findings from previous reports.[16,17]

In the present study, the 28% proportion of early DON lesions detected with MRI and the 19% prevalence of definite ischaemic necrosis in our cohort of musculoskeletal DCS divers is higher than expected since recreational divers are supposed to perform dives with conservative exposure. Unfortunately, the increase in number of scuba divers during the last decade who go deeper, for longer, and use gas mixtures containing helium implies that this population will probably be at greater risk to develop DON in the future, on a level similar to professional divers and caisson workers. The reported prevalence of DON ranges from 0–4% in military divers to 50% in native diving fishermen, and even 70% in Turkish sponge divers.[7,8,12,19,20] These varying rates can be explained by different and often poor decompression practices, the lack of recruitment standards and periodic medical examination and the presence of predisposing factors for avascular necrosis (e.g., alcohol intake, hyperlipidaemia) in the latter groups. Nearly 30% of professional divers who have had a history of limb DCS have been reported to have subsequent bone lesions.[10,11] The present study is the first to analyse the association between musculoskeletal DCS, early bone marrow damage and DON development in recreational divers. Recently, we have described two divers in whom MRI examination performed 24 hours after HBO treatment for a painful shoulder following scuba air dives showed multiple micro-cavities in the fatty marrow cavity highly consistent with bubble formation (Figure 2). Bone scintigraphy obtained the day after confirmed the hypovascularization of the affected area and, six months later, control MRI revealed extensive DON in both divers.[21]

The proposed mechanism linking DCS and DON is based on the hypothesis of elevated intramedullary pressure resulting from bubble formation in the marrow cavity during decompression. Expansion of bubbles in the fatty tissue of bone may be responsible for pain by irritating nerve endings located in marrow sinusoids or near the periosteum, but may also contribute to the reduction of blood flow, with resultant vascular stasis, ischaemia and 'compartment syndrome' of bone. If high intramedullary pressure is sufficiently prolonged death of both marrow and calcified bone may occur.[22] However, it is thought that bubble formation is not sufficient to cause DON and that there may be some other predisposing factors for ischaemic bone necrosis, such as fat embolism, hyperoxia and hypoxia, coagulation abnormalities and rapid rates of compression.[23–26]

Interestingly, we have noticed that divers who presented with bone infarction often complained of increased pain during hyperbaric treatment.[21] Statistical analysis confirmed this impression and this was the only predictor of ischaemic abnormalities detected with MRI in this series of divers. We propose that the rapid compression induced a rise in intra-osseous pressure in the rigid marrow cavity previously altered by intramedullary bubbles, thus producing subsequent ischaemic pain in the affected area. Expansion of gas bubbles during the initial phase of oxygen recompression might also contribute, as demonstrated experimentally.[27] This raises the question of whether prompt hyperbaric treatment is beneficial or deleterious.

The average time to recompression was 8.0 h in the DON group versus 4.5 h in the non-DON group. Although not statistically different in this small study population, the increased delay could be another contributory factor; prompt recompression has been reported to prevent DON occurrence after musculoskeletal DCS using a sheep model.[28,29] However, in those studies, hyperbaric exposure was prolonged, similar to saturation dive with provocative decompression, excluding a possible comparison with our data.

Our results are limited by the lack of statistical power of this preliminary cross-sectional study due to the small sample size of divers with musculoskeletal DCS. Another limitation is a possible selection bias with respect to including more serious cases of bends only (i.e., that divers with mild symptoms did not present for treatment) and with respect to MRI examinations (prevalence of DON lesions in musculoskeletal DCS under reported due to the loss of four patients to MRI follow up). Further work including more data from additional hyperbaric facilities is needed to confirm the present findings.

Conclusion

Musculoskeletal DCS in recreational diving was seen following dives considered to carry a high risk for bubble production. The prevalence of definite DON was 19% in our cohort, suggesting that MRI for routine screening is justified in recreational divers treated for musculoskeletal DCS before they return to diving. Increasing pain during hyperbaric treatment should be considered as the intra-osseous manifestation of limb bends, requiring early MRI

examination of the affected area post treatment. However, the benefit of MRI in detecting initial bone marrow lesions before conversion into subsequent osteonecrosis has not been determined. Iterative sessions of hyperbaric oxygen could limit ischaemic necrosis as suggested in a recent pilot study dealing with early-stage avascular necrosis of the femoral head,[30] but the possibility that prompt recompression could worsen the initial damage remains debatable.

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Dive problems and risk factors for diving morbidity

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Key words
Diving accidents, risk factors, buoyancy, scuba diving, DAN – Divers Alert Network

Abstract
(Buzzacott P, Denoble P, Dunford R, Vann R. Dive problems and risk factors for diving morbidity. *Diving and Hyperbaric Medicine*. 2009;39(4):205-9.)
Introduction: Running out of air, buoyancy problems and rapid ascents are known risk factors for diving morbidity and mortality. The effects of the diving environment and equipment and the influence of individual diver characteristics on these risks were studied.
Methods: Between 1995 and 2004, Project Dive Exploration prospectively recorded 52,582 recreational dives made by 5,046 adult divers. Data regarding diver characteristics, dive environment, recorded depth-time profiles and reported dive problems were collected. Ascent rates were calculated from depth-time profiles. Human factors (age, sex, certification status) were tested by logistic regression for association with running out of air, buoyancy problems and rapid ascents. To control for human factors, dives where a problem was reported (case dives) were compared to dives made by the same divers in which each risk factor was not reported (control dives), again using a logistic regression model.
Results: Running out of air and buoyancy problems were significantly associated with older females, whereas rapid ascents were associated with younger males. Certification status also affected which type of problem was experienced. Maximum depth and dive time had only weak effects upon the type of problem experienced. All three problems were associated with charter boat and live-aboard diving, the most significant environmental association being the perceived workload of the dive.
Conclusions: We recommend dive instructors give greater emphasis during training to monitoring gas reserves, buoyancy control techniques and slow ascents, coupled with practical methods of gauging ascent rate. Dive boat crews should consider likely workloads when selecting dive sites and warn divers against overexertion.

Introduction

Among recreational divers, three leading causes of morbidity and mortality are drowning/near drowning, barotraumas due to expanding air whilst ascending and decompression illness (DCI), caused by the dissolution or forceful introduction of gas, forming bubbles within bodily tissues.[1–6] Running out of air, a loss of buoyancy control and making a rapid ascent have been found to be associated with these types of diving morbidity and mortality.[6–11] These risk factors are also known to occur concurrently.[11–13]

A retrospective review of 100 consecutive Australian diving fatalities separated contributing factors into three types: human, environmental and equipment.[5,14,15] Using a similar classification by dividing the data into either human (diver) or environmental/equipment (dive) characteristics, we hypothesized human characteristics would have a greater impact than environmental/equipment characteristics on the likelihood of running out of air, losing buoyancy control and/or making a rapid ascent.

Methods

Between 1995 and 2004, Project Dive Exploration (PDE) collected diver demographic data and dive profiles from recreational divers on live-aboards and day boats and/or making shore dives. Divers were approached at the commencement of a dive series at popular recreational dive sites, including in the Caribbean, Scapa Flow and Grand Cayman, and were asked to complete a survey and to record dive data after each dive. Depth-time dive profiles recorded by dive computers manufactured by Suunto, Cochran, DiveRite, Uwatec and Sensus data-loggers manufactured by ReefNet were divided into dive phases and the rate of the final ascent to the surface was calculated.[16] Ascents faster than 18.3 $m.min^{-1}$ over at least the last 6.1 metres' sea water (msw) were classified as 'rapid'. Following each dive, divers were asked to report any problems they had experienced, selecting problems from a list. Characteristics of the dive site were recorded, such as the diving environment (e.g., ocean/river/lake) and dive platform (e.g., shore/charter boat/live-aboard). Duke University Institutional Review Board approved the protocol with a waiver of written informed consent since provision of the data implied consent. Data were checked for accuracy and false dives, for example recorded during post-dive gear washing, were removed from the dataset, leaving 56,205 dives made by 5,374 divers. A further 3,623 dives were removed (dives for training, research or commercial work, or involving trimix and rebreathers, or by children), leaving 52,582 recreational open circuit dives on air or nitrox to 40 msw or less, made by 5,046 adults.

Potential factors associated with running out of air, buoyancy problems and making a rapid ascent were classified as human (diver) or environmental/equipment (dive) factors. Human factors included age, sex, and level of dive certification.

Environmental/equipment factors included maximum depth, dive time, dive platform (shore/pier/small craft or charter boat/live-aboard), perceived workload during the dive (resting/light or moderate or severe/exhausting), exposure protection (dive-skin/wetsuit or drysuit), thermal comfort (cold/very cold or warm/pleasant), and gas breathed (air or nitrox).

A data subset of human factors was created wherein each diver was included just once and, using a logistic regression model, divers who reported running out of air, a buoyancy problem, making a rapid ascent or who recorded a rapid ascent during at least one dive were compared to divers who did not report or record those events. To then control for these human factors, four more data subsets were created wherein each dive was included where a diver had reported running out of air, a buoyancy problem, making a rapid ascent or where a diver recorded a rapid ascent (case dives), and also included in each subset were dives where the same divers did not report or record these events (control dives). Divers who made only dives during which a risk factor was reported, or who made only dives during which no risk factors were reported, were excluded from the four matched-control data subsets. Therefore, the resulting four subsets each contained only dives made by divers who had both reported or recorded at least one of the dive problems and who had also made dives where no problem was reported or recorded.

STATISTICS

Data were managed using Microsoft Access and analysed using SAS (Cary, NC), version 9.1. A logistic regression model was fitted to human factors variables by backwards elimination and variables with $P > 0.05$ were removed. Dive differences between case dives and matched control dives in the four environmental/equipment subsets were also tested by logistic regression and accepted at $P \leq 0.05$.

Results

The human factors data subset contained 5,046 adult recreational divers. Of those, complete data was obtained for 4,711 (93%) regarding age, sex, and diver certification level. Running out of air was reported by 65 of those divers (1.4%), problems with buoyancy by 223 divers (4.7%) and making a rapid ascent by 235 divers (5.0%). Dive profile loggers and personal dive computers also recorded 181 divers (3.8%) who ascended at least once by 6.1 msw or more at a rate greater than 18.3 $m.min^{-1}$. Certifications were collapsed to three levels: basic, advanced open water diver, and specialty or higher. These diver characteristics are presented by risk factor in Table 1.

Of the 52,582 adult recreational dives, 46,801 (89%) had no missing data for dive depth, dive time, dive platform, diving dress, gas mixture breathed (air or nitrox), reported thermal comfort and perceived workload. As described above, one subset each was created for running out of air (n = 86/1,293 dives, 6.7%), a buoyancy problem (n = 362/3,174 dives, 11%), reporting a rapid ascent (n = 296/2,598 dives, 11%), and recording a rapid ascent (n = 227/1,803 dives, 13%). Dive characteristics for each risk factor are presented in Table 2.

HUMAN FACTORS

Divers who reported running out of air at least once were slightly older (Odds ration (OR) per additional year 1.03, 95% CI 1.00, 1.05, $P < 0.03$) and more than twice as likely to be female as those not running out of air (OR 2.36, 95% CI 1.44, 3.86, $P < 0.001$).

Divers who reported a buoyancy problem at least once were again more likely to be female (OR 2.35, 95% CI 1.79, 3.09, $P < 0.0001$) and slightly older (OR 1.02 per year, 95% CI 1.01, 1.03, $P = 0.0036$), and also more likely to have basic diver certification rather than specialty or higher (OR 1.83, 95% CI 1.27, 2.66, $P < 0.005$).

Divers who reported making a rapid ascent at least once were slightly younger (OR per year 1.02, 95% CI 1.01, 1.03, $P < 0.001$) and more likely to have specialty or higher training (OR 3.37, 95% CI 2.3, 4.9, $P < 0.0001$).

Table 1
Human characteristics by risk factor for 4,711 divers

Variable	Running out of air (n = 65)		Buoyancy problem (n = 223)		Reporting a rapid ascent (n = 235)		Recording a rapid ascent (n = 181)		Overall (n = 4,711)	
Number male n (%*)	33	(51)	113	(51)	177	(75)	141	(78)	3,308	(70)
Age y (SD)	45.1	(11.9)	44.1	(11.5)	40.4	(10.4)	40.6	(11.0)	42.2	(11.1)
Certification										
Basic n (%)	30	(46)	112	(50)	44	(19)	90	(50)	1,916	(41)
Advanced n (%)	26	(40)	71	(32)	99	(42)	29	(16)	1,496	(32)
Specialty n (%)	9	(14)	40	(18)	92	(39)	62	(34)	1,299	(28)

* Percentages rounded to nearest whole number

Table 2
Dive characteristics by risk factor for 4,711 divers recording 46,801 dives

Variable	Running out of air (n = 86)		Buoyancy problem (n = 362)		Reporting a rapid ascent (n = 296)		Recording a rapid ascent (n = 227)		Overall (n = 46,801)	
Maximum depth *msw* (SD)	22.5	(8.2)	20.5	(7.3)	21.4	(7.8)	20.3	(7.0)	20.9	(7.8)
Dive time *mins* (SD)	45.8	(14.6)	45.4	(13.3)	41.1	(13.3)	33.7	(15.1)	50.9	(14.7)
Ascent rate *m.min^{-1}* (SD)	7.3	(5.9)	6.4	(7.8)	8.8	(8.1)	25.0	(9.9)	5.9	(5.2)
Dive boat *n* (%*)	77	(90)	305	(84)	273	(92)	196	(86)	40,257	(86)
Drysuit *n* (%)	5	(6)	39	(11)	198	(67)	67	(30)	5,278	(11)
Nitrox *n* (%)	14	(16)	33	(9)	105	(35)	34	(15)	9,935	(21)
Felt cold *n* (%)	7	(8)	58	(16)	60	(20)	28	(12)	4,598	(10)
Workload										
Low *n* (%)	59	(69)	223	(62)	151	(51)	154	(68)	37,706	(81)
Medium *n* (%)	20	(23)	122	(34)	102	(34)	64	(28)	8,296	(18)
High *n* (%)	7	(8)	17	(5)	43	(15)	9	(4)	799	(2)

* – Percentages rounded to nearest whole number

Likewise, divers who recorded a rapid ascent were more likely male (OR 1.45, 95% CI 1.01, 2.08, $P < 0.05$) and more likely to have specialty or higher training (OR 2.43, 95% CI 1.56, 3.82, $P < 0.0001$).

DIVING FACTORS

Dives during which divers reported running out of air were likely to have been slightly deeper (OR per msw 1.05, 95% CI 1.02, 1.08, $P < 0.02$), slightly shorter (OR per min 1.02, 95% CI 1.00, 1.04, $P < 0.05$), from a live-aboard or charter boat (OR 3.88, 95% CI 1.89, 7.94, $P < 0.0005$), and to have also reported a higher perceived workload (OR 3.72, 95% CI 1.50, 9.26, $P < 0.005$).

Dives during which divers reported a buoyancy problem were more likely to have been made from a live-aboard or charter boat (OR 1.40, 95% CI 1.03, 1.90, $P = 0.03$), to have involved air rather than nitrox (OR 2.30, 95% CI 1.57, 3.35, $P < 0.0001$), to have been reported as strenuous (OR 2.04, 95% CI 1.16, 3.60, $P < 0.0001$) and to have also been slightly shorter (OR per min 1.03, 95% CI 1.02, 1.04, $P < 0.0001$).

Dives during which a rapid ascent was reported were also more likely to be slightly shallower (OR 1.05 per m, 95% CI 1.03, 1.06, $P < 0.0001$), slightly shorter (OR 1.03 per min, 95% CI 1.02, 1.04, $P < 0.0001$), more likely from a charter boat or live-aboard (OR 1.82, 95% CI 1.14, 2.91, $P < 0.02$) and were reportedly more strenuous (OR 8.77, 95% CI 5.52, 13.89, $P < 0.0001$).

Dives during which an ascent rate of greater than 18.3 m.min^{-1} was recorded over at least 6.1 m were also more likely to be slightly shallower (OR 1.04 per m, 95% CI 1.02, 1.06, $P < 0.0001$), slightly shorter (OR 1.05 per min, 95% CI 1.04, 1.06, $P < 0.0001$), and more likely from a charter boat or live-aboard (OR 2.36, 95% CI 1.58, 3.53, $P < 0.0001$). Of the 227 recorded rapid ascents, only 28 (12%) were reported as a dive problem. An overall summary of significant associations is presented in Table 3.

Discussion

The human characteristics of age, sex and certification status appear to affect the likelihood of reporting a known risk factor for diving morbidity, and the positive or negative effect of these characteristics appears to differ between types of dive problems. Older females were more likely to run out of air or report buoyancy problems, whereas younger males ascended faster and were more likely to report a rapid ascent. Curiously, the effect of increasing certification status appears to reduce the risk of reporting a buoyancy problem yet increase the risk of ascending rapidly. That buoyancy problems were more common with low certification status was not surprising, but why higher certification resulted in ascending faster was not apparent in this study. Initially we considered the possibility that higher-certified divers were diving to deeper depths and perhaps struggling with increased volumes of air that would need to be released during ascent, but when we compared the dives where ascents were rapid to dives made by the same divers but which did not end with a rapid ascent we discovered that rapid ascents, either recorded or reported, were associated with shallower depths. We wonder now if divers are generally more attentive when diving deeper, or perhaps more carefree if they can see the surface when they commence their final ascent.

The most interesting finding though was that all four dive problems were associated with live-aboard or charter boats.

Table 3
Summary table of odds ratios by risk factor; high-cert – higher certification; low-cert – low certification

Variable	Running out of air		Buoyancy problem		Reporting a rapid ascent		Recording a rapid ascent	
Human	Female	(2.36)	Female	(2.35)	High-cert	(3.37)	High-cert	(2.43)
	Older	(1.03)	Low-cert	(1.83)	Younger	(1.02)	Male	(1.45)
			Older	(1.02)				
Environment/	Dive boat	(3.88)	Air	(2.30)	Strenuous	(8.77)	Dive boat	(2.36)
Equipment	Strenuous	(3.72)	Strenuous	(2.04)	Dive boat	(1.82)	Shorter	(1.05)
	Deeper	(1.05)	Dive boat	(1.40)	Shallower	(1.05)	Shallower	(1.04)
	Shorter	(1.02)	Shorter	(1.03)	Shorter	(1.03)		

The weak yet significant association with shorter dive times is likely a consequence of being told when to return to the boat, but strenuous dives (when divers reported their perceived workload as "*severe*" or "*exhausting*") were strongly associated with running out of air, buoyancy problems and reporting a rapid ascent. We wonder if divers are being taken to sites they subsequently discover are more challenging than anticipated, especially older divers and females who, for example, may perceive a moderate current or long surface swim to be harder work than younger males do. Regardless of the underlying cause, we recommend dive crew advise divers before each dive to consider the potential for physical stress.

Divers wearing drysuits accounted for 11% of the 46,801 dives with no missing values, yet they accounted for 60% (n = 1,571) of the 2,598 dives made by divers who made both dives in which they reported ascending rapidly and also dives in which they did not. Likewise, drysuit wearers accounted for 29% (n = 531) of the 1,803 dives made by divers who made both dives during which they recorded a rapid ascent and dives in which they did not, which was again far more common than in the total dataset (29% versus 11%). Drysuits clearly appear to be associated with a fast rate of ascent and anecdotal free-format comments recorded on the data-collection form support such an association, yet diving dress was dropped early from each regression model. This was almost certainly because divers did not change their type of diving dress during participation in this study and so, therefore, the likelihood of ascending rapidly did not change due to diving dress. This may explain why Table 2 has such high numbers of drysuit wearers associated with reporting and/or recording rapid ascent, yet diving dress was not found to be significant.

Because data were complete for 93% of the divers and 89% of the dives, the relatively high prevalence of running out of air (1.4% of divers) and ascending faster than a commonly recommended maximum rate[17] (3.8% of divers) is in itself cause for concern, especially as the majority of those who ascended too rapidly did not report it. It is noteworthy that few people who reported a rapid ascent actually exceeded 18.3 m.min^{-1}, and few people who exceeded 18.3 m.min^{-1} later reported it as a problem. Of the 227 dives where a rapid ascent was recorded by computer, 199 (88%) were made by divers who were either unaware of their ascent rate, ascended rapidly during the dive at a time other than the final ascent, or who may have defined rapid ascent differently from the criteria used in this study. Greater emphasis upon ascent rates during training may reduce speed of ascent among divers of the future.

There were 46,801 dives with no missing data regarding environmental and equipment factors, and 86 of those (0.18%) ran out of air, 362 (0.77%) reported buoyancy problems, 296 (0.63%) reported a rapid ascent and 227 (0.49%) recorded a final ascent faster than 18.3 m.min^{-1} over at least 6.1 msw. At first glance the prevalence of these problems appears relatively low. To put these findings into perspective, if this were an accurate estimate of the prevalence likely to be experienced by a dive boat taking 25 divers out for two dives per day during 200 days per year (10,000 diver-dives per annum), they could expect divers to run out of air during 18 dives, 77 divers to have reported buoyancy problems, 63 reports of ascending rapidly and 49 dives with a recorded rapid ascent (43 of those in addition to six who would report the rapid ascent), making a total of 201 problems per year, or an average of one event per day. Because these problems are known risk factors for the most common types of diving morbidity and mortality, even such a low prevalence as we report here should be cause for concern aboard dive boats of all sizes.

In conclusion, we recommend dive instructors give greater emphasis during basic diver training to monitoring gas reserves, effective buoyancy control techniques (especially when using drysuits) and the importance of ascending slowly, coupled with practical methods of gauging ascent rate, (such as monitoring the depth-meter rather than looking up to the surface). We especially encourage commercial dive boat crew to consider the workload likely to be experienced when selecting dive sites and to warn divers against overexertion.

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Genitourinary infection and barotrauma as complications of 'P-valve' use in drysuit divers

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Key words
Drysuit, technical diving, infectious diseases, barotrauma, genitourinary tract, equipment, case reports

Abstract

(Harris R. Genitourinary infection and barotrauma as complications of 'P-valve' use in drysuit divers. *Diving and Hyperbaric Medicine*. 2009,39(4):210-12.)
Drysuits are commonly worn by divers undertaking long exposures in cold water. The need to urinate during such dives leads to the use of a variety of devices to conduct urine from the diver to the ambient water. The final common pathway to the water is via a suit bulkhead known as a 'P-valve'. Use of the various urinary devices and P-valve can lead to a number of complications including urogenital sepsis, pneumaturia and genital squeeze. The urinary devices in current use are described, then four clinical cases that illustrate the complications are presented. Recommendations for prevention of these complications are made.

Introduction

Drysuits are worn as thermal protection when diving in cold water, when exposures are prolonged or as physical protection when the water is contaminated. The need to urinate while wearing a drysuit during lengthy dives has led to the development of techniques and devices that allow this. The increasing popularity of technical diving has seen more divers with this need.

Male divers use either nappies or a condom catheter system. In the latter case, an adhesive urinary condom catheter is attached to the penis before the drysuit is donned. The condom is then connected to a plastic or rubber tube that exits the drysuit via a special bulkhead valve known as a 'P-valve'. Female divers have been limited in their choice of technique. Absorbent nappies have been the mainstay for women in drysuit diving but more recently devices like the Shewee Go® or She-P® (Figure 1) have offered an alternative. In female divers, a latex or silicone cup is either held against or adhered to the external genitalia collects then drains urine via an identical tubing system to that utilised by male divers. These systems may effect an airtight seal as with the male condoms.

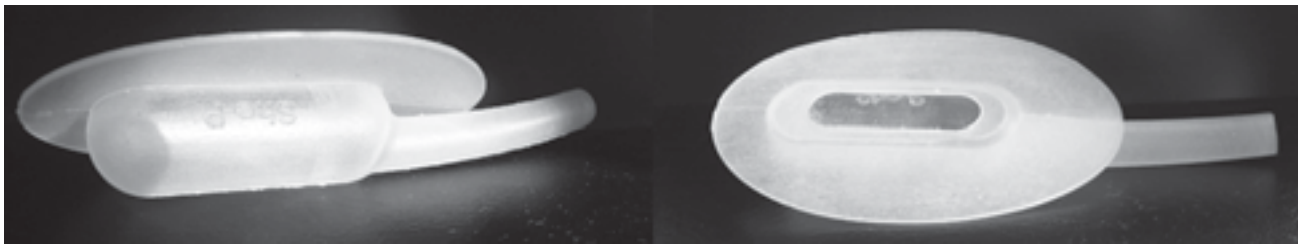
P-valve systems come in two basic varieties: unbalanced or balanced. In the unbalanced version, a screw valve on the outside of the suit is opened when the diver wishes to urinate. This is usually closed after urinating to prevent drysuit flooding in the event the condom falls off or becomes disconnected. The balanced P-valve utilises an additional chamber (inside the suit) to equalise the pressure within the tubing with the ambient pressure (Figure 2). One-way check valves may also prevent suit flooding in the event of accidental disconnection.

The use of P-valves and their accessories is not free of complications, and five complications in three divers relating to their use are reported here. These include catheter squeeze, urogenital infections and pneumaturia.

Case one

A technical diver approximately 40 years of age was involved in a two-week diving project on a shipwreck in the Sea of Marmara, Turkey. The diver was performing one decompression dive per day to a maximum of 70 metres' sea water (msw) using a closed-circuit rebreather. Thermal protection was drysuit based. During the dives urination was facilitated via an unbalanced P-valve. After approximately five days of diving, the subject developed symptoms and signs consistent with urinary sepsis: initially malaise,

Figure 1
A commercially available female urine collecting system, the 'She P'®

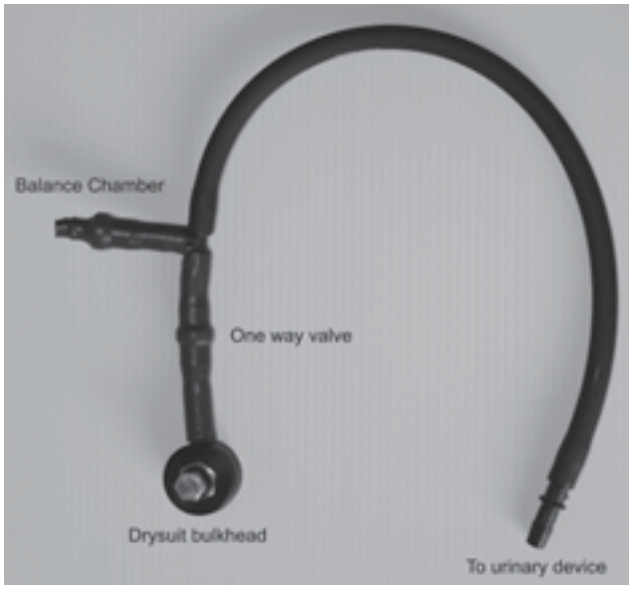


vomiting and dysuria, which progressed to loin pain, fever and rigors. Due to the remoteness of the location, empirical treatment was commenced with intravenous gentamicin and ciprofloxacin, and rehydration. The diver's condition gradually improved over the next 24 hours. Follow-up testing could demonstrate no abnormality on urine microbiology, plain abdominal X-ray looking for calculi, or ultrasound scan of the urogenital tract.

Case two

The author, a 44-year-old cave diver, was about to submerge in the cold (6.5^{O}C) waters of an Australian cave. He was standing in chest-deep water and opened his unbalanced P-valve in order to urinate before commencing the dive. At that moment, he distinctly felt some cold water flow in a retrograde fashion through the condom catheter into his bladder. Approximately 48 hours later he began to feel systemically unwell: initially malaise and anorexia, then diarrhoea and night sweats. The following day he developed dysuria, frequency and urgency. Loin pain and rigors followed, suggesting urinary tract infection. Moderate discomfort in the perineal region also raised the possibility of acute prostatitis. The author attended a hospital emergency department and was treated with intravenous gentamicin and cephalothin, and discharged with oral cephalexin. Symptoms were very slow to settle over the next seven days and so the antibiotic was changed to oral norfloxacin with good effect. Initial urine microbiology was negative but microscopy showed large numbers of white and red blood cells.

Figure 2
A 'balanced' (left/right) P-valve system, showing the balance chamber and one-way valve. The drysuit bulkhead can also be seen; this tube can be connected to either a male (condom catheter) or female (e.g., the 'She P'®) urine-collecting system



Six weeks later, the symptoms suddenly recurred in the absence of diving. On this occasion, urine culture grew *Pseudomonas aeruginosa*, sensitive to norfloxacin. Prostate-specific antigen was high at 11 ug.L^{-1} (normal range 0–4). Plain abdominal X-ray, and renal and prostatic ultrasound were normal. A diagnosis of relapsing acute prostatitis was made and was successfully treated with a two-month course of oral norfloxacin.

Case three

A 49-year-old drysuit diver performed a 60-minute, 7-msw dive in the ocean. He was using a condom catheter connected to a balanced P-valve. Twenty-five minutes into the dive he attempted to urinate. He immediately felt a sharp pain in the penis, forcing him to abort the dive and ascend. Assuming the tubing to the P-valve was obstructed, he inflated his drysuit fully and managed to ease his discomfort somewhat. He finished the dive and, after exiting the water, opened his drysuit to find the condom "ballooned" with urine secondary to a kinked tube distally.

That night he developed dysuria, constipation, generalised aching and 'flu-like' symptoms. He then developed urinary frequency, fever and rigors. The next day he was admitted to hospital with a urinary tract infection, where he remained for six days on intravenous antibiotics (drug unknown). Urine and blood cultured *Pseudomonas aeruginosa*.

Case four

The author can also report on a dual complication relating to an unbalanced P-valve. On a drysuit dive to 60 metres' fresh water in a sinkhole, inadequate drysuit inflation led to a sudden and distressing sensation of a "squeeze" on the condom catheter and penis. This required immediate action on the part of the author with a two-part remedy. Firstly the suit was inflated with compressed air to decrease the overall drysuit squeeze. Secondly, the screw valve on the bulkhead was opened to decompress the offending tubing. The author experienced dramatic relief, but also noted a disturbing retrograde flow of what felt like air into his bladder as the valve was opened. On surfacing after the dive, these events were confirmed by the presence of bruising on the distal portion of the penis, and pneumaturia that persisted for the next 12 hours.

Discussion

The use of P-valves and urinary condom catheters is commonplace in male drysuit divers. The new devices now available for women may form an airtight seal and so in theory may generate a similar set of complications. In males between the ages of three months and 50 years, acute bacterial urogenital tract infection is a rare event in the absence of an anatomical abnormality, a disorder of bladder emptying or a mechanical 'breach' of the body's normal defences (such as catheterisation).[1] Hence, it is likely that

the use of P-valves in the divers described was causative in the urogenital infections the divers experienced.

The origin of the *Pseudomonas sp*. in two of the divers is likely to be the drysuit tubing. After diving, the drysuit is stored and residual urine or water will dwell in the P-valve tubing. This is a perfect culture medium for *Pseudomonas*. In the author's view, the bacteria are far less likely to be introduced from the cave or ocean environment in these cases. The proposed mechanism for these infections is by retrograde inoculation with bacteria into the urogenital tract, or from bacteria in the tubing being held in close proximity to the urethral meatus. The fact that retrograde flow can occur in this setting was clearly demonstrated by the presence of pneumaturia in case four.

Pseudomonas sp. are tolerant to a wide variety of physical conditions including high salt concentrations, low nutrient concentrations and weak antiseptics. The organism is flagellated and motile, aiding movement through aqueous media.[2] Urinary tract infections caused by *Pseudomonas aeruginosa* are usually hospital-acquired and related to urinary tract catheterisation. Community-acquired pseudomonas urosepsis is far less common.[3] Because of its frequent resistance to antibiotics and its production of potent endotoxins, Gram-negative pseudomonas sepsis carries significant morbidity and mortality. In these cases, routine follow-up investigations looking for calculi or anatomical anomalies were non-contributory. This further suggests that a mechanical breach of normal defences, or direct inoculation into the urethral meatus was the cause.

Two divers were using unbalanced P-valves. The use of balanced systems with their one-way valves should in theory prevent any retrograde flow of air or water into the diver, and hence reduce such complications. However, an obstruction to flow in case four still may have generated some retrograde movement of urine into the urethra despite the use of a balanced P-valve. One strategy for users of unbalanced valves is to 'prime' the tubes with incompressible urine before entering the water. More care with equalising the drysuit to ambient pressure during descent may also prevent retrograde flow through the drainage system, as well as avoiding squeeze of the external genitalia. Commencing the dive with the P-valve in the open position should also prevent squeeze, but increases the risk of a suit flood in the event of accidental disconnection of the tubing.

Perhaps the most important strategy in the prevention of urinary sepsis is adequate cleaning of the P-valve tubing after use and before storage. Syringing an antiseptic such as chlorhexidine through the tubing could accomplish this. Alternatively a solution of methylated spirits and acetic acid (3:1) might be used, as it appears to be effective in preventing pseudomonas infections (e.g., in the external ear canal).

A final complication of the drysuit P-valve is catastrophic suit flooding. Any breach in the system e.g., accidental disconnection of the tubing from the condom catheter in conjunction with a failure to close the external bulkhead, will allow the drysuit to fill with water. Water in the drysuit will not only increase the risk of hypothermia but may adversely affect the diver's buoyancy, and prevent them surfacing. A major drysuit flood in very cold water, in a diver with a decompression obligation of several hours, may well have a fatal outcome.

An informal survey by the author of drysuit divers via an internet forum and an email list, also revealed numerous episodes of urinary tract infections, genital squeeze, positive pressure incidents and pneumaturia associated with the use of newer urine-collecting devices in women, and condom catheters in men. Therefore, this is a potentially serious problem that could lead to long-term health problems in divers undertaking prolonged dives in drysuits. Education in cleaning and care of these devices should become part of technical diving training.

Conclusions

To the author's knowledge these are the first documented cases of complications arising from the use of P-valves in drysuit divers. Complications like urogenital sepsis in males and females, pneumaturia and external genital squeeze may be significantly under-reported. The use of balanced (c.f. unbalanced) P-valves may decrease the likelihood of all these complications arising. Greater awareness of these problems may lead to earlier recognition, diagnosis and treatment of urogenital sepsis; whilst better technique and improved post-dive hygiene may decrease the incidence of the complications described.

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Short communication

The impact of performing spirometry on shunting across a patent foramen ovale

Ian EC Maddox, David R Smart and Warrick LJ Bishop

Key words
Patent foramen ovale (PFO), echocardiography, scuba diving, decompression illness, pulmonary function

Abstract

(Maddox IEC, Smart DR, Bishop WLJ. The impact of performing spirometry on shunting across a patent foramen oval. *Diving and Hyperbaric Medicine*. 2009;39(4):213-5.)
Transient changes in intrathoracic pressure can alter left and right intra-atrial pressures, and may provoke shunting of blood across a patent foramen ovale (PFO). Spirometry causes a transient rise and subsequent fall in intrathoracic pressure that, if performed following a dive on compressed air, could raise the risk of decompression illness by arterialisation of venous bubbles across a PFO. To assess whether spirometry can provoke right-to-left shunting across a patent foramen ovale, a subject with a known PFO, previously identified by bubble contrast transthoracic echocardiography, where shunting was only evident on performing a Valsalva manoeuvre, underwent re-examination whilst performing spirometry. Right-to-left shunting was not evident at rest, but was provoked by performing spirometry. If spirometry is to be performed within two hours of surfacing, this should be regarded as a potential risk for decompression illness.

Introduction

The termination of manoeuvres that transiently raise intrathoracic pressure is recognised to cause a rise in right atrial pressure relative to left atrial pressure.[1,2] This fact is utilised in the echocardiographic diagnosis of a patent foramen ovale (PFO), where bubble contrast may be seen to cross from right to left atrium following such a manoeuvre.[1–4]

An ongoing study investigating lung function pre- and post-recreational scuba diving requires volunteers to perform spirometry before a dive and in the period following surfacing.[5] Venous bubbles commonly form following recreational scuba dives on air.[6] It is possible that increased right atrial pressure relative to the left atrium may occur following spirometry. In the setting of venous bubbles, this may provoke their arterialisation across an undiagnosed PFO, increasing the risk of decompression illness (DCI). This possibility was investigated in a subject with a known PFO.

Methods

The subject (author IM, who gave informed consent) was known to have a PFO, previously identified by transthoracic bubble contrast echocardiography, where right-to-left shunting was evident only following a Valsalva manoeuvre. Re-examination by transthoracic bubble contrast echocardiogram was undertaken by the same operator (author WB). The subject was examined in the left lateral position. Bubble contrast medium was prepared by agitating 9 ml of saline with air by repeated injection and aspiration from the ampoule. One ml of the subject's blood was added to this agitated saline and visible gross air bubbles expelled from the syringe. Once good apical, four-chamber views were obtained, this agitated saline/blood mix was injected via an 18-gauge cannula into a right antecubital vein, and the echocardiogram scrutinised in real time for the appearance of bubble contrast in the chambers of the heart. The echocardiogram images were also recorded electronically. Following an interval of about five minutes, the subject performed spirometry using a Spirolab II portable spirometer, whilst remaining in the left lateral position with the four chamber views maintained. A single vital capacity inspiration was followed immediately by forced expiration through the spirometer. Agitated saline with blood was injected intravenously as before at three seconds after the onset of the forced exhalation, and the echocardiogram images viewed and recorded. After a further interval, spirometry, injection of agitated saline with blood and echocardiogram examination were repeated in the same manner. In both instances, the duration of forced expiration was almost exactly four seconds.

Results

With the subject at rest, and no airway or thoracic manoeuvres being undertaken, no bubbles were detected in the left atrium or left ventricle during the seven monitored cardiac cycles following detection of bubbles in the right atrium. No right-to-left shunt was demonstrated (Figure 1).

Figure 1
Bubble contrast is seen entering the right atrium (RA) and right ventricle (RV), but none in the left heart chambers; no thoracic or airway manoeuvres have been performed

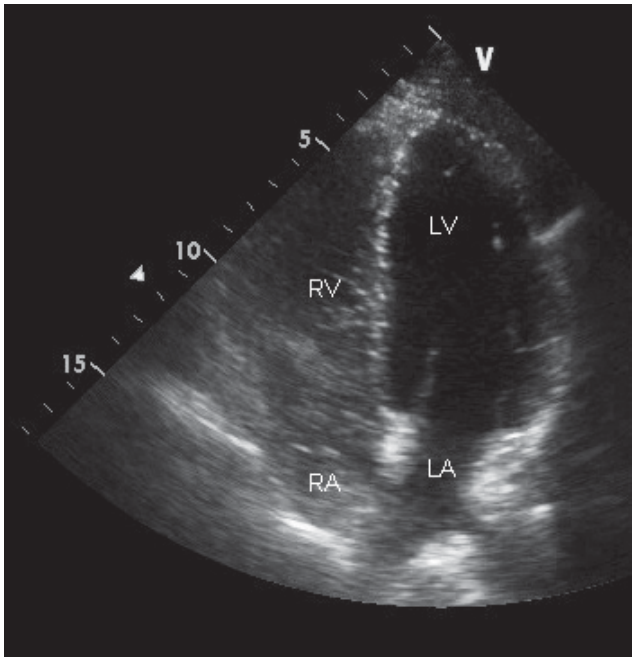
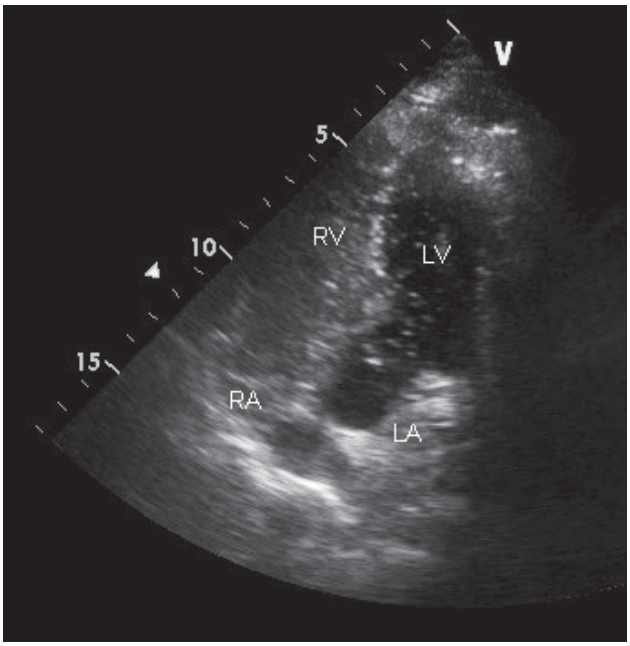


Figure 2
Following spirometry, bubble contrast is seen in the left ventricle during atrial systole, within two cardiac cycles of its appearance in the right atrium



After performing spirometry, followed by inspiration, bubbles were visible in the left atrium and ventricle within two cardiac cycles of their detection in the right atrium. Repeat spirometry again demonstrated bubbles in the left atrium and ventricle within two cardiac cycles of their detection in the right atrium (Figure 2). No further study was performed as, although published data suggests bubble contrast studies are very safe, repeated injection could risk significant paradoxical air embolism in the subject.[7,8] The appearance of bubbles in the left atrium and left ventricle within three cardiac cycles of their appearance in the right atrium suggest shunting at the atrial level rather than at the transpulmonary level.[4]

Discussion

Patent foramen ovale is common and usually goes undiagnosed.[9] There is a recognised association of PFO with decompression illness.[1,3,4,9–12] In one study amongst a group of scuba divers, there was a prevalence of 22% of PFO of a physiological size that, according to the research, significantly increased the risk of major DCI.[3]

PFO-related DCI is presumed to be caused by paradoxical nitrogen bubble embolisation through the interatrial septum.[11] Nitrogen washout models support the hypothesis that it is subsequent growth of these arterial bubbles due to tissue gas supersaturation that is the cause of the link between the PFO and inner ear DCI.[12] These models also circumstantially support the suggestion that tissue supersaturation is relevant to other organ systems whose vulnerability to DCI is associated with right-to-left shunts.[12] Under normal physiological conditions, passage of blood and bubbles from right to left atrium is limited. The PFO may be a valve-like structure, which is closed during 95% of the cardiac cycle due to higher pressures in the left atrium.[11]

In using a bubble-contrast echocardiogram to investigate the presence of a PFO, the aim is to induce a right-to-left shunt. Some authors have recommended this be avoided shortly after any DCI as there is the potential to exacerbate neurological injury. It has been suggested that activities occurring during or soon after diving that cause a transient rise with subsequent release of pressure, such as manoeuvres to clear ears, straining to lift dive equipment or climbing onto a boat, may provoke right-to-left shunting of bubbles across a PFO and increase the risk of DCI.[1,10] It should be emphasised that it is the release of the raised intrathoracic pressure that causes the significant increase in right atrial pressure compared to the left.[2]

The demonstration in a single subject of the provocation of a right-to-left shunt by performance of spirometry does not fully mimic the conditions that occur when spirometry is performed after diving. Our subject lay in the left lateral position as opposed to standing upright. This may facilitate right-to-left shunting by increasing flow from the lower body into the right atrium at the release of the raised intrathoracic

pressure. Whilst sub-xiphisternal views with the subject semi-reclining may have mimicked more closely the real-life situation, we were concerned that, in this position, adequate images may not have been obtained, especially given the large thoracic excursions proposed. Nevertheless, this study raises the concern that spirometry in the period following a dive may increase the risk of DCI, especially as multiple attempts may be required to produce satisfactory respiratory data.

How might the possible increased risk of DCI by performing post-dive spirometry be minimised? Logically, spirometry should be performed in the period following surfacing when venous bubble load is at a minimum. Venous bubbles can be present for up to two hours after scuba dives on air.[13] One study of sports divers reported a Spencer Doppler bubble grade of at least III in 8 out of 28 divers within ten minutes of surfacing at a rate of 17 metres per minute, from a dive of 25 minutes at a depth of 35 metres' sea water.[6] A study examining decompression stress in hyperbaric chamber attendants by Doppler analysis found significant inter- and intra-individual variability even during a single, tightly controlled profile.[14]

Conclusion

In a single subject, spirometry induced sufficient changes in haemodynamics to provoke shunting across a PFO. This has implications for safety if spirometry is performed post-diving in subjects who may have a PFO. If spirometry is to be performed within two hours of surfacing, this should be regarded as a potential risk for DCI and preparations should be made to deal with such an event.

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Editor's note:
A link to the full echocardiographic study will be made available soon on the EUBS and SPUMS websites.

Review articles

Therapeutic agents from the sea: biodiversity, chemo-evolutionary insight and advances to the end of Darwin's 200th year

David J Newman, Gordon M Cragg and Christopher N Battershill

Key words
Marine animals, biology, ecology, pharmacology-marine, drugs, malignancy, general interest

Abstract

(Newman DJ, Cragg GM, Battershill CN. Therapeutic agents from the sea: biodiversity, chemo-evolutionary insight and advances to the end of Darwin's 200th year. *Diving and Hyperbaric Medicine*. 2009;39(4):216-25.)
Drugs from the sea? Darwin may not have considered this concept when he was thinking about mechanisms that drove diversification of life on earth. In recognition of his 200th year, and celebration of the publication in 1859 of his *On the origin of species*, we review the global status of marine biodiscovery in medicinal fields, with a focus on the South Pacific. Furthermore, in the Darwinian spirit, we touch on putative evolutionary drivers and the chemical ecology of the successful leads. We argue that, for the relatively limited investment in effort to date, the success of marine leads as therapeutics promotes enhanced focus on marine biodiversity as a source of useful medicinal agents. The simple prime argument in support of this is the fact that we can exploit over four billion years of evolution in combinatorial chemistry in marine organisms, directed at relevant and effective biological activity.

Drugs from the sea

The beginning of marine biodiscovery and the vision of marine-derived drugs on the market can be traced to discoveries by Bergmann and the subsequent identification of spongothymidine and spongouridine in the early 1950s from the Caribbean sponge *Tethya crypta*.[1–3] The subsequent explosive discovery of compounds is described in the citations by Suckling and Newman et al.[4,5] These discoveries led to the identification of a close analogue, cytosine arabinoside, as a potent antileukaemic agent that was commercialised subsequently as Ara-C. Other closely related compounds such as adenine arabinoside (Ara-A), an antiviral compound later also found in the Mediterranean gorgonian *Eunicella cavolini*, and azidothymidine (AZT), can be traced back to this initial discovery.

The advent of scuba techniques approximately 60 years ago and their subsequent utilization by natural-products chemists, and biologists working closely with them, led to questions as to how marine sessile organisms defend themselves against predation, competition and disease. Very early on, the chemical diversity, complexity and novelty of marine extracts were appreciated and since Bergmann's discoveries, exciting modes of biological activity of relevance to humans have been reported.[6] In this, the 200th year celebrating Darwin's birth and his insight into biodiversity and evolutionary process, we should not be surprised that potent, chemotherapeutically relevant chemical leads can be readily discovered from marine organisms for a substantial range of clinical applications. These compounds are secondary metabolites with many natural functions selected for in an evolutionary context; they represent the front-line defence for most marine organisms, particularly in those sedentary, soft-bodied filter feeders where cellular challenge from pathogenic micro-organisms is ever-present.

The metabolites need to be potent because of immediate dilution on being exuded, highly targeted in mode of action (conservation in the metabolic process minimises generalist bioactivity), and they need to get into the cells of other organisms to effect a response (Figure 1). Such qualities are also the attributes of effective drugs. Furthermore, when considering the lowest metazoans, possessing essentially the same basic biochemical pathways as higher vertebrates, there has been over 800 million years of evolutionary-scale experimentation resulting in a highly varied and flexible repertoire of biologically active chemistry.[7] However, the evolution of marine invertebrates and algae cannot be considered in isolation, since many marine organisms are likely to be influenced by, or share or benefit from the biochemistry of microbial symbionts. Thus, exploration of the full range of marine micro- and macro-diversity arguably harnesses four billion years of selective pressure directing biosynthesis of defensive metabolites toward functional biological activity. The result is sophisticated chemical flexibility producing an amazing array of compounds and compound classes.[8,9] These exciting biological activities, once discovered and fine tuned with medicinal chemistry to therapeutic targets, will be the drugs of the future.[10–12]

Biodiversity equates to chemical diversity

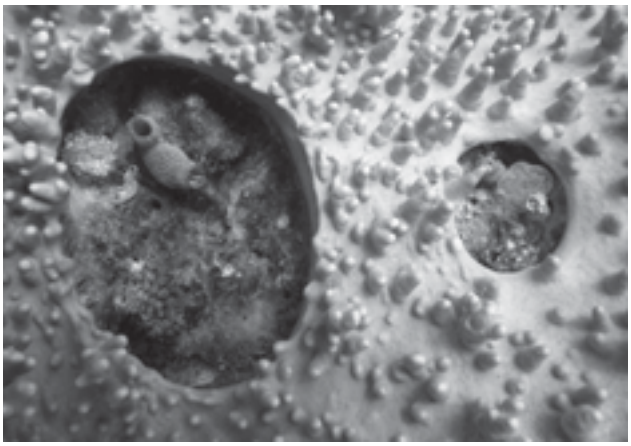
There is a rich and growing library of review articles focusing on the sources of new drugs and their properties. A few of the more prominent and relevant to the topic

at hand are cited above. Natural product-derived drugs have been used in all therapeutic areas: as anti-malarials, anti-virals, anti-fungals, anti-tuberculosis treatment, anti-HIV agents, anti-inflammatory agents, for osteoporosis, Alzheimer's disease and other neurological diseases and disorders.[13–15] They are also the source of many biomedicinal tools and have been used extensively as probes in medicinal research.[16] Synthesising across many review papers, over 75% of all drugs used as anti-cancer, anti-infective and anti-cholesterolaemic agents come from or have their synthetic origin, be it the scaffold, warhead or concept, in nature. This is because, even though natural products arise from a limited selection of simple biochemical building blocks and biosynthetic pathways, the diversity of structure and function created under almost limitless natural recombination far exceeds that possible in synthetic libraries.[17]

Furthermore, this process is guided by selective pressure at the very coal-face of survival for almost all benthic marine species including micro-organisms, as it is through their 'defensive chemistry' that they either survive to reproduce, or die. Increasingly we realise that this chemistry has many roles, from causing the eliciting organism to be toxic or distasteful, to more subtle biological acitivities such as mediating rapid cellular growth and loss of adhesion (by which sponges, for example, can slough off settling epizoic organisms such as bryozoans) or to cause cells in encroaching species to cease to divide, thereby effecting a competitive standoff and maintenance of occupied reef territory (Figure 1).

It does not take much imagination to visualise applied uses for such compounds on the understanding that the molecules are designed to be effective on multicellular animal life. Therefore, sampling biodiversity across a full phylogenetic range will yield diverse new chemical classes and novel biologically active compounds. Over 90% of all macro-organism phyla on the planet occur on the seafloor, equating to an unprecedented molecular diversity of secondary metabolites, enzymes and biochemical pathways.[18] This diversity pales into insignificance when compared to that of marine micro-organisms, where recent work on metagenomic diversity in seafloor sediments or in the water column suggests a limitless biological resource with, for example, over 20,000 microbial entities in one litre of seawater and an estimated 36 x 10^{30} cells in the oceans.[19]

Figure 1
Zones of growth inhibition in the soft coral *Lobophytum* sp. surrounding *Didemnum molle* (a green ascidian, left) and *Lissoclinum patella* (a white translucent ascidian, right) on a shallow-water coral reef (courtesy E. Evans-Illidge, AIMS)



Marine natural products

The body of research and development of drugs is too large to effectively review here; hence the remainder of the paper will focus largely on anti-cancer drugs and marine natural products. It is, however, interesting to review briefly the role of marine natural products in drug-development programmes for other important therapeutic areas.

Arguably the world's number-one killer is malaria, with 1–2 million deaths a year and 300–500 million new clinical cases reported annually. Of 621 terrestrial plant species screened, 82 (13.2%) were found to have significant anti-malarial activity (IC_{50} <10ug.mL^{-1}).[13] Although the total number of marine extracts screened was not stated, but is likely to be much less, 27 compounds that have anti-malarial activity were reported.[13] These compounds were isolated from sponges, gorgonians, octocorals and ascidians, also from cyanophytes and red algae, and included compounds such as sesquiterpenes, diterpenes, peptides, glycosides and alkaloids. Of note are the manzamine alkaloids from symbionts of the Pacific sponge *Petrosia* sp., that are currently under development.[10,13,20] The species that elicit these compounds are invariably ones that are found in densely encrusting communities or are even epizoic in habit. They are known to possess rich bacterial symbiotic populations. They would likely come into contact with pathogens (fungal and other infections) and would exist in conditions where competition for space was heavy. An arsenal of biologically active chemistry for defence would be expected.

Natural products are growing in prominence as anti-HIV agents in an expanding search for treatments for this, the world's fourth biggest killer, with over 60 million people having been infected by 2005. Alkaloids, coumarins, flavonoids, lignans, phenolics, quinones, saponins, terpenes and sterols, xanthones, carbohydrates, peptides and proteins have all been sourced from nature. Of 122 compounds reported in a 2005 review as being of considerable interest in the development of anti-HIV agents, 19 were from marine sources, 15 being sponge-derived compounds.[21] The relatively low number of marine candidates to date may reflect the traditional focus on terrestrial plant-derived compounds, given these leads make up the sources of almost all of the other compounds reviewed, rather than superior efficacy of terrestrial over marine leads. Nevertheless, given

the probable sampling bias, marine and particularly sponge-derived leads are prominent. Again on examining the habitats and growth characteristics of the source marine species, we find that they are predominantly species that are soft-bodied and either occupy densely encrusted habitats where forms of chemical defence rather than structural armament are commonplace or where the host sponge harbours diverse bacterial communities.

Naturally occurring anti-mycobacterial drug leads have also traditionally been sought from terrestrial plant sources, although again there is growing interest in marine leads.[14] Of 91 lead compounds reviewed including alkaloids, flavonoids, terpenoids, steroids, phenols and peptides, 40 were plant derived, 22 from terrestrial fungi and eight synthetic. Despite relatively little focus to date, marine leads account for 22% of the anti-mycobacterial leads of current interest.[14] The marine leads listed come almost exclusively from gorgonians and ascidians, with the most active compound a marine pyridoacridine coming from a *Didemnum* species. All of the ascidian leads are species that are aggressively epizoic in nature, overgrowing and often killing their host, frequently causing secondary fungal and other infections in the process. Therefore, some self-defence against the collateral damage of overgrowth activity would be expected. It would be useful to test the hypothesis that the compounds elicited in this competitive process are the same ones that we find of use for human treatment.

Marine natural products as anti-cancer agents

AGENTS IN CURRENT CLINICAL TRIALS

The following review represents a selection of the more prominent marine natural product drug leads currently in the clinic; it is not exhaustive. Full details may be found in papers by Newman, Cragg and others cited below. In keeping with the thrust of this article, we annotate this summary with comments as to the natural origin of the target molecules.

Bryostatins

In 1968, the US National Cancer Institute (NCI) commissioned a large-scale (for those days) collection of the bryozoan *Bugula neritina* for chemical workup. The aqueous isopropanol extract was tested for intrinsic activity as an antitumor agent in the then current P388 and L1210 murine leukaemia *in vivo* models. The extract was found to be inactive against L1210, but using the P388 model at the same concentration gave a 68% increase in life span.[22] After further painstaking and difficult research, the compound was purified and identified as bryostatin 3, one of a series of closely related compounds that now number twenty.[23,24]

Subsequent work identified two other geographic areas where significant (in relative terms) quantities of bryostatin 1 could be isolated from *B. neritina* colonies. By 1990, there was enough cGMP-grade (current Good Manufacturing Practice) material to commence systematic clinical trials, though prior to this time frame, small quantities of bryostatin1 had been supplied to a variety of collaborators so that basic biochemical studies and initial clinical trials could be performed in the United Kingdom.

From these studies, it was shown that bryostatins bind to the same receptors as the tumour-promoting phorbol esters, the protein kinase C isozymes, but have little or no tumour-promoter activity. To date, bryostatin 1 has been studied in more than 80 human clinical trials, usually as a single agent. It has become evident that this is not the optimal treatment regimen, with improved responses being reported for combination studies with fludarabine at the Phase I level. Combination studies with biological agents, such as interleukin-2 or granulocyte macrophage-colony stimulating factor, the nucleoside derivative cytarabine or other cytotoxic agents such as paclitaxel, vincristine or cisplatin, are currently in progress. These combinations are being tested against various forms of leukaemia as well as against other carcinomas.[25] (For data from NCI clinical trials, see their website <http://clinicaltrials.gov>.)

Bryostatin is also in the early stages of being assessed as an anti-Alzheimer's drug, with Phase I trials to be initiated soon. Supply remains an issue for this compound, synthesis being difficult in the extreme. Of significance here is the identification of the gene cluster that would produce the 'hypothetical bryostatin precursor, bryostatin 0'.[26] If this gene cluster can be expressed in a heterologous host (currently the genetic source is the as yet uncultured symbiont *Candidatus endobugula sertula*), then the production of significant quantities of base structural material may be possible. *B. neritina* is a cosmopolitan fouling bryozoan, found on most wharf pilings and ships' hulls around the world. It is an aggressive coloniser, but it does not always possess the bryostatin metabolites; samples tested from Australia and New Zealand possessed no bryostatins. Haygood and colleagues are currently working on the wider chemical ecology of this species.

Dolastatin derivative TZT-1027 (auristatin PE or soblidotin)

The original compounds, the 'dolastatins' were first sourced from *Dollabella* nudibranchs. As a result of the synthetic processes developed in early studies on dolastatin 10, many derivatives of the dolastatins were synthesized, with TZT-1027 entering Phase I clinical trials in Europe, Japan and the USA. This compound is also known as auristatin PE and soblidotin. It has had a fairly chequered career thanks to the machinations of the pharmaceutical industry. Initial Phase I and II clinical trials were terminated, but currently a new series of Phase I trials has commenced. Of interest is that the compound is also a vascular disrupting agent, causing the vasculature within tumours to collapse.[27] Currently it is in three clinical trials, from Phase I to Phase III, using auristatin PE linked to specific monoclonal antibodies.

Dolastatin derivative ILX651 (synthadotin)

As in the case of soblidotin, this compound has also had a chequered career as companies were bought and sold. It is orally active and had advanced to Phase II trials in a variety of cancers, but those trials ceased. It then entered into a Phase I trial in the USA against solid tumours. Recently it was reported that ILX651, in fact, might be a relatively weak prodrug for the functionally active tasidotin C-carboxylate which is 10–30 times more potent in an *in vitro* assay of purified microtubule dynamics.[28] However, the compound has recently been withdrawn from trial. Although a moot point now, the source of the dolastatins has recently been shown to be microbial (as with the bryostatins), with a report of the direct isolation of dolastatin 10 from a marine cyanobacterium known to be grazed on by *Dolabella auricularia*.[29] Of relevance in a biodiscovery sense, the nudibranch acts as a useful sequestering agent of these and many other compounds. Without the nudibranch, these compounds, which occur in low concentration in benthic symbiotic associations, might not have been discovered.

Kahalalide F

This cyclic depsipeptide was isolated from the Sacoglossan mollusc *Elysia rufescens* following grazing by the mollusc on a green macroalga *Bryopsis* sp.[30] It was synthesized in a very efficient manner using solid-phase peptide techniques and in 2000 entered Phase I clinical trials in Europe for the treatment of androgen-independent prostate cancer.

There are a variety of mechanisms attributed to this compound. It was known to target lysosomes, suggesting selectivity for tumour cells with high lysosomal activity, such as prostate tumours.[31] Kahalalide F was shown to induce cell death via 'oncosis' (the progression of cellular processes leading to necrotic cell death) possibly initiated by lysosomal membrane depolarization in both prostate and breast cancer cell lines.[32] Then in 2005, HepG2 cells were reported to demonstrate significant alterations in their membrane permeability with cell swelling/blebbing, implying specific interactions with membranes and/or proteins at 300nM.[33] It has also been reported to induce a necrosis-like cell death involving inhibition of protein kinase B signalling and depletion of ErbB3. ErbB3 may well be a marker for progress against suitable tumour types, and an ErbB3 kinase inhibitor may well increase efficacy.[34] Recently a Patent Cooperation Treaty international application was successfully filed by another group claiming production of kahalalide F and other derivatives from a *Vibrio* species isolated from *Bryopsis* and *Elysia rufesens*, implying that the invertebrate obtains the producing microbe from the alga and then maintains it as a symbiont.[35] Thus, there is a potential renewable source of these agents by use of fermentation.

Aplidine

This compound, formally known as dehydrodidemnin B, was first reported in a patent application in 1989, with a UK patent issued in 1990, and then referred to in a paper on the structure-activity relationships amongst the didemnins.[17] The initial work on aplidine, its entry into Phase I and II trials and the preferred method of synthesis were described in detail in 2004.[36] At that time, the dose-limiting toxicity was muscle pain, responsive to either dose limitation or addition of carnitine, which increased the maximum tolerated dose by 40%. Several Phase II clinical trials are now underway in Europe for acute lymphoblastic leukaemia, lymphoma, multiple myeloma, prostate and bladder cancer. The precise mechanism of activity (MOA) of this agent is not yet known, but it appears to block vascular endothelial growth factor (VEGF) secretion and blocks the corresponding VEGF-VEGF-receptor-1 (also known as *flt-1*) autocrine loop in leukaemic cells.[37] Aplidine and kahalalide F are also being studied in psoriasis targets.

Ecteinascidin 743 (Yondelis®)

Although antitumour activity from the ascidian *Ecteinascidia turbinata* had been reported as early as 1969, it was not until 1990 that the structure of the most active component, known as Et743 from the absorption maximum, was published.[38,39] The yield from natural sources was very low, and in order to provide enough material to perform basic *in vitro* and *in vivo* studies on the MOA, considerable amounts of the ascidian had to be collected from areas around the Caribbean. The compound was subsequently synthesized in a chemical *tour de force* and a refined process reported that produced Et743 in higher yields.[40]

The requirement for supply of material for further pre-clinical and clinical development, included large-scale wild collections, and aquaculture both on land and in sea, but for late cGMP-grade clinical and commercial supply, an elegant 21-step semi-synthesis from the marine *Pseudomonas fluorescens* metabolite cyanosafracin B was devised. This was feasible in spite of a low overall yield of 1.4% because the starting material could only be obtained on a large scale by fermentation.[36]

Several reports over the last few years give some indication of the likely MOA(s) for Et743 when tumour cells are treated *in vitro.* A major problem has been that the concentrations used in these experiments were often orders of magnitude greater than those physiologically relevant *in vivo.* Since the latter levels are in the low nanomolar to high picomolar range, care should be taken when evaluating published work on the MOA of this compound. At *in vivo* concentrations, the MOAs of Et743 have been shown to include effects on the transcription-coupled nucleotide excision repair process and interaction between the Et743 DNA adduct and DNA transcription factors, in particular the NF-Y factor. Recently pharmacogenomic analyses have identified a series of genes involved in the sensitivity of tumour cells to this agent.[34] Prior to the establishment of mechanisms of action, the compound was placed into human clinical trials and in 2001,

Et743 was licensed under the generic name trabectedin (brand name Yondelis®). Details of the trials and methods were reported in a 2005 review.[36]

As a result of these earlier trials, Et743 was pre-registered in the European Union (EU) and granted orphan drug status for sarcoma by the European Commission's Committee for Orphan Medicinal Products of the European Agency for the Evaluation of Medicinal Products (EMEA). Following a somewhat chequered path through the EMEA, the compound was approved within the EU in late 2007 for commercialization for the treatment of sarcoma, becoming the first 'direct from the sea' compound to reach that goal as an antitumor treatment. Since 2007, there have been six clinical trials listed on the NCI trials website, plus at least four others in Europe in the Prous Integrity® database. It is hoped that these will lead in due course to approvals for use in the treatment of other types of cancer. Again, the source organism is a very successful cosmopolitan biofouling species, and the elicited chemistry of interest to medicine is likely to have beneficial properties in nature. The chemical ecology of *E. turbinata* is the topic of much interest.

Zalypsis (PM-00104)

This compound is a synthetic derivative of jorumycin (from a mollusc) or the renieramycins (from sponges), and entered Phase I clinical trials from 2005 in both the USA and Europe. It is reported from genomic analyses to have a similar mechanism to that of Et743 in terms of inducing double-stranded breaks in DNA, though, to date, details have only been presented as a meeting abstract.[41] It will be interesting to follow this compound in comparison to Et743.

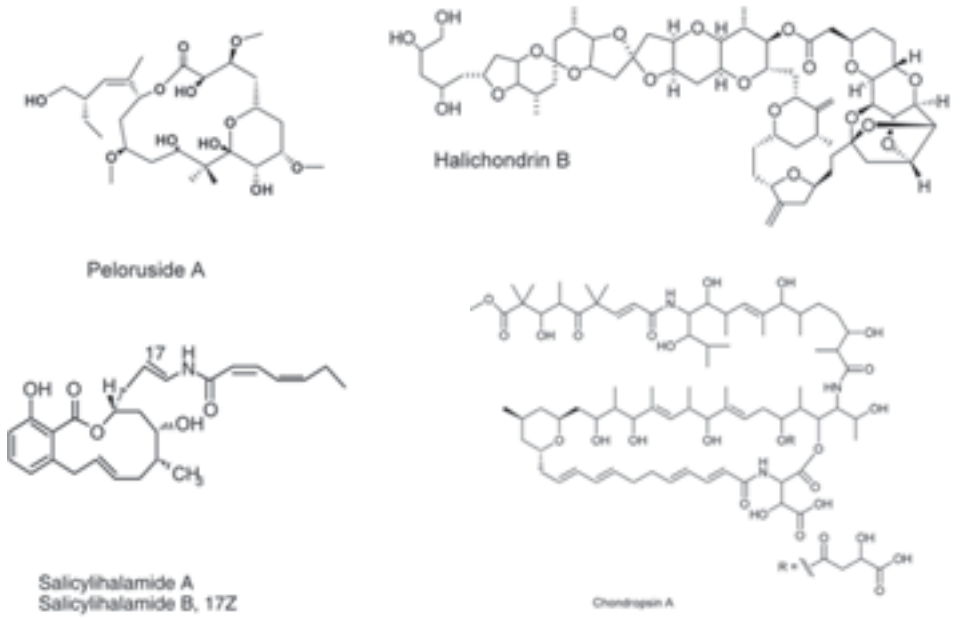
Eribulin (E-7389)

This agent, modelled from the naturally occurring antitubulin compound, halichondrin B (Figure 2) arose from another synthetic tour de force utilizing the synthetic method for halichondrin B combined with the realization that the active part of the molecule resided in the macrolide ring (approximate molecular weight (MW) 600; right-hand end of molecule shown in Figure 2) and not in the 'tail' (the remaining 400 of the overall 1000 MW).[42] Over 200 different molecules have been synthesized, the modified, truncated, macrocyclic ketone (E-7389) being chosen as the candidate compound.

This molecule, like its parent, is a tubulin-interactive agent with very potent activity at the nanomolar level *in vitro* and recent modelling studies suggest that it binds at or close to the 'vinca site'.[43] Since tubulin is a dynamic dimer and no high resolution X-ray crystallographic structure exists, the 'putative binding sites' on the tubulin molecule are defined by displacement binding assays. Thus the 'vinca site' is the site that the vinca alkaloids bind to and can be displaced from by other compounds. Similarly, the 'laulimalide site' (see later) is different from the vinca site, as laulimalide can be displaced by other agents, but not by the vinca alkaloids. This is a biochemical concept that is used in many assays for beta-agonist binding sites.

Halichondrin B, the source molecule, is one of at least nine other halichondrin molecules, variations on the halichondrin scaffold but with widely varying biological activities. Originally found in small quantities in a Japanese *Halichondria* species, the bulk of the preparative

Figure 2
A sample of South Pacific marine natural products that have demonstrated anti-tumour activity



work was carried out on halichondrin B extracted from the sponge *Lissodendoryx* sp., discovered by Munro and Blunt in partnership with the NCI. Halichondrin B and its sister molecules are biosynthesised by *Lissodendoryx* sp. (and probably its symbionts) continuously, but with seasonal peaks and in heightened yields when the sponge is challenged with competitors, (such as didemnid ascidians, Battershill CN, unpublished data). During a programme to produce enough sponge for extraction to progress pre-clinical trials, aquaculture-produced sponge was found to elicit halichondrin B (as well as the other halichondrins) even after three years in 'in-sea' culture, suggesting a very stable association with symbionts in a biosynthetic partnership. Heightened yields of halichondrin B on exposure to competing species or in response to damage suggest these metabolites are defensive in function.

Salinosporamide A (NPI-0052)

This compound, in addition to having an unusual structure, is also the first of what may well be a future wave of compounds to enter clinical trials. It was produced by a marine-derived streptomycete of an entirely new genus and species, *Salinispora tropica*. It is also unusual in that it has gone from initial discovery to clinical trial in only four years, a testament to the researchers at Scripps Oceanographic Institution and Nereus Pharmaceutical in San Diego.[44]

Over the last 20 or so years, there has been much discussion on whether a number of the agents found in marine invertebrates had 'microbe(s) in their background', such as using genomic information in the cases of bryostatin and Et743 and by direct isolation of microbes from the *Bryopsis*

Table 1
Status of marine-derived natural products in clinical and preclinical trials (updated from reference 12)

Compound	Source	Habitat/ecology	Development	Status
Didemnin B	*Tridemnum solidum#*	fouling	Phase II (cancer)	dropped mid-90s
Dolastatin 10	*Dolabella auricularia* (marine microbe; cyano)	sequestered	Phase I/II (cancer)	no further trials
Girolline	*Pseudaxinyssa cantharella*	lagoonal sponge community	Phase I (cancer)	discontinued
Bengamide	*Jaspis* sp.#	dense encr., sediment	Phase I (cancer)	Novartis, discontinued
Cryptophycins	*Nostoc* sp., *Dysidea arenaria#*	dense encr., sediment	Phase I (cancer)	Lilly, now Sanofi-Aventis
Bryostatin 1	*Bugula neritina#*	fouling	Phase II (cancer)	one trial going
Ecteinascidin	*Ecteinascidia turbinate#*	dense encrusting	Phase II/III (cancer)	approved as Yondelis®
Aplidine	*Aplidium albicans#*	dense encrusting	Phase II (cancer)	PharmaMar
E7389 (Hali B)	*Lissodendoryx* sp.	sediment	Phase I (cancer)	Eisai
Discodermolide	*Discodermia dissoluta*	microbial symbionts	Phase I (cancer)	Novartis, discontinued
Kahalalide F	*Eylsia rufescens, Bryopsis* sp.#	sequestered?	Phase II (cancer)	licensed to PharmaMar
Spisulosine	*Spisula polynyma*	surf clam	Phase I (cancer)	discontinued
HTI-286	*Cymbastella* sp.#	dense encrusting	Phase II (cancer)	Wyeth, work stopped
KRN-7000	*Agelas mauritianus*	sponge gardens	Phase I (cancer)	
Squalamine	*Squalus acanthias*	spiny dogfish	Phase II (cancer)	macular degeneration
Laulimalide	*Cacospongia mycofijiensis*	dense encrusting	preclinical (cancer)	
Curacin A	*Lyngbya majuscula#*	sediment, fouling	preclinical (cancer)	
Vitilevuamide	*Didemnum cucliferum, Polysyncraton lithostrotum#*	dense encrusting	preclinical (cancer)	
Diazonamide	*Diazona angulata*	dense encr. (cave)	preclinical (cancer)	
Eleutherobin	*Eleutherobia* sp.#	dense encrusting	preclinical (cancer)	
Sarcodictyin	*Sarcodictyon roseum*	dense encr./fouling	preclinical (cancer)	
Peloruside A	*Mycale hentscheli#*	dense encr., fouling	preclinical (cancer)	licenced to Reata
Salicylihalimide	*Haliclona* sp.	dense encrusting	preclinical (cancer)	
Thiocoraline	*Micromonospora marina*	isolated from sea sand	preclinical (cancer)	
Variolins	*Kirkpatrickia variolosa*	dense encrusting	preclinical (cancer)	
Dictyodendrins	*Dictyodendrilla verongiformis*	dense encrusting	preclinical (cancer)	licensed to Taiho
Manoalide	*Luffariaella variabilis#*	dense encr., sediment	Phase II	discontinued
IPL-576,092	*Petrosia contignata*	sponge garden	Phase II	licensed to Aventis
Ziconotide	*Conus magus*	toxin	Phase III (pain)	approved for pain
CGX-1160+	*Conus geographus, catus, victoriae*	toxin	Phase I (pain)	

Epizoic habit; encr. - encrusting

Figure 3
Phylogenetic origin of anti-cancer leads currently in the clinic or in late phase pre-clinical trial with the US National Cancer Institute[12]
Phyla: CY Cyanophyta; CHL Chlorophyta; RHO Rhodophyta; PHA; Phaeophyta; POR Porifera; BRY Bryozoa; COE Coelenterata; MOL Mollusca; ECH Echinoida: CRU Crustacea; ASC Ascidiacea.

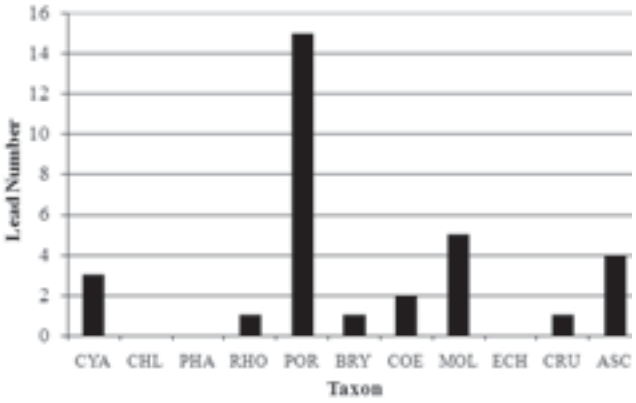
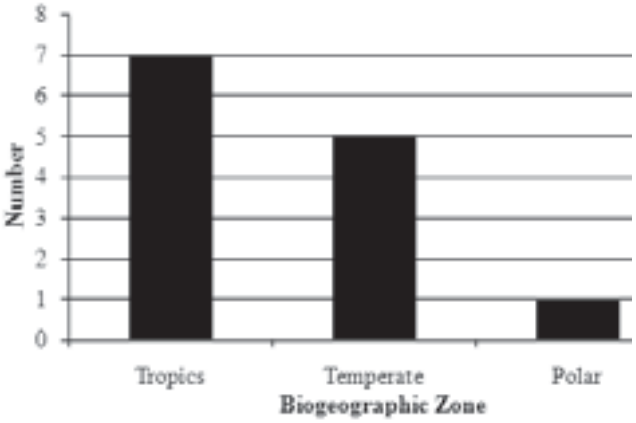


Figure 4
Source biogeographic regions for the marine cancer leads currently in late phase pre-clinical trial or in the clinic



alga in the case of kahalide F. Fenical and Jensen, at Scripps, proposed, however, that there were deep-sea, free-living microbes that could be cultivated and novel agents produced by modifications of methods used for other microbial flora. This hypothesis has since proved to be correct.[44]

The structure of salinosporamide A is reminiscent of the terrestrial bacterial product omuralide, a known proteasome inhibitor, and such activity was reported in the original publication.[44] The compound had an unusual chlorine substitution and within a year or so, two research groups had synthesized the base molecule.[45,46] In addition, the necessary cGMP product for clinical trials could be produced by fermentation in a saline environment, the first time that this task had been performed successfully on any scale with a marine-sourced microbe. During these runs, several other salinosporamide derivatives were isolated and other secondary metabolites were further explored. The compound entered Phase I clinical trials in 2006, initially against solid tumours and leukaemias and, in 2007, a Phase I trial against multiple myeloma was initiated.

There is an updated 'marine pharmacology website' that is kept relatively up to date as to the current (usually within the last six months) status of marine natural products as drugs (<http://marinepharmacology.midwestern.edu/>).

Ecological and phylogenetic trends

An updated summary of marine leads in late-phase pre-clinical trials or in the clinic as of 2004 is reproduced from Cragg and Newman in Table 1.[12] Details have been added (where known) about the habitat or habits of the source organism. In most cases, compounds of interest are derived from species found in densely encrusted communities where competition for space is high, hence biosynthesis of allelopathic and immunosuppressive compounds likely. Alternatively, the source organisms are species from fouling communities in high sediment environments where pathogenic attack is commonplace. They are also species that do not have highly elaborated skeletal armament, but tend to be soft-bodied and, where known, are host to a diverse array of symbionts.

For anti-cancer leads, sponges (Porifera) are clearly the lead taxon (Figure 3), possibly as they have need for subtle forms of chemical defence. For an organism defending space, as most benthic encrusting species need to do, it is to their advantage not to kill encroaching species outright but to inhibit their growth such that a standoff is maintained. Otherwise in killing the neighbour, the space created if not immediately occupied by oneself, may be colonised by a more competitively aggressive occupant. In surveys of reef systems around the world from the tropics to the poles, standoff competitive outcomes represent 95% of the encounters, frequently with a chemically maintained no-growth zone between neighbours in evidence (Figure 1). Therefore, elicited defensive compounds act to halt cellular replication in target tissues and appear to have similar functions when addressed to human cancer cells. Marine and sponge metabolites have been shown to be active through all stages of the cell cycle, resulting in cell stasis, which is why they have such strong interest to drug-development agencies.[10]

While there have been attempts to identify high-yielding biogeographic regions (as Figure 4 might suggest), the pattern of decreasing incidence of anti-tumour active leads with increasing latitude possibly reflects more the greater effort that has gone into tropical collection compared to the polar regions than any true biogeographical distribution. However, the Australasian region appears to produce a disproportionately large number of leads, given the relatively

low level of collection activity to date (Table 1). From a collection of approximately 1,500 samples in New Zealand, there are three candidate compounds in clinical or late phase clinical trial (halichondrin B derivatives, variolins, and peloruside A, Figure 2). From Australian collections of 3,000 samples, three vacuolar-ATPase active compounds made it to the Federal Register (chondropsin A, salicylihalamide A and lobatamide A, Figure 2). Until recently these had not been progressed due to issues of availability, both in terms of physical supply and legal provenance; now both solved. Australia is also the source of manoalide and a number of conotoxins, as well as a large number of other biologically active metabolites such as the phorboxazoles. It is clear that the South Pacific is a rich source of novel, biologically active compounds and most nations in the region are currently developing legislative and collaborative research mechanisms to enhance discovery of useful leads.

The future

As can be seen from the number of comments about the involvement of microbes in the production of materials obtained from marine invertebrates, and the discovery of marine-derived Gram-positive microbes from the Actinomycetales, it is becoming evident that a large proportion, perhaps even the majority, of chemical compounds of interest isolated from marine sources are produced by unicellular organisms (eubacteria, archaea or eukarya). These are then possibly modified by the host invertebrate in some cases, rather than being the direct product of the invertebrate. When one realizes that over 50% of the body mass of the *Porifera* (sponges) is composed of microbes, this does not seem quite such a leap of faith. There are some interesting reviews on sponge-associated microbes that are worth reading by a wider audience than just those working in the microbial field.[47,48] The relevance of the macro-organism is its role as the discoverable source of the target compound, even if that is biosynthesised by the microbe. Furthermore, evidence suggests that such biosynthesis may not occur without some stimulus from the host or particular micro-environmental conditions.

Finally to demonstrate the potential of the *Porifera*, in particular, the story of peloruside is quite instructive in that it is now known to be produced by a variety of sponges of the genus *Mycale*. Depending on its location around New Zealand, different mixtures of peloruside with other secondary metabolites are found.[49] As with *Lissodendoryx* sp. and halichondrin B, and indeed with two Australian leads examined to date; salicylihalamide A from *Haliclona* sp. and manoalide compounds from *Luffariella variabilis*, the yields of the target metabolites may vary with season. This variation is repeated through the years, and the yields have been maintained in aquaculture in either as good as or above naturally occurring levels, indicating a stable biosynthetic system.[50–52] Chemico-ecological studies suggest some environmental influence, but further work examining the chemical micro-ecology is needed to fully appreciate the role of these metabolites in nature and how they are biosynthesised. An outcome of such work will be novel production options including metagenomic expression and perhaps even semi-synthetic improvement in the range of metabolites produced, with heightened specificity for new therapeutic targets.[53] The complex structures of these molecules (Figure 2) has been a key issue limiting investment in and updating of natural marine products as drug candidates. Breakthroughs in sustainable and economic supply of these leads will herald a new age of drug discovery sourced from the sea.

To further highlight the potential of the South Pacific, the lead compound peloruside A is demonstrating some very interesting synergistic activities with taxoid-site drugs and apparently binds at the so-called 'laulimalide site' on the tubulin dimer but does not exhibit synergy with the latter compound.[54] Major joint studies are being performed on the synthesis of peloruside A, including investigation of other synthetic routes. Further details as to the intrinsic activities/MOA of this agent will be very interesting to follow as they come to light.[55]

When one couples these data with the explosion in secondary metabolite-cluster recognition resulting from current research in the microbial world (even fungi have clustered secondary metabolite genes), then the potential for novel compounds and the ability to produce them via fermentative means, perhaps using surrogate hosts, should be considered seriously. This would remove the major perceived hindrance to studies of marine-derived compounds by the larger pharmaceutical houses.

The reader will have noticed that the pathway to drug development is a frustratingly tortuous one with entry in and out of pre-clinical and clinical trial. In true Darwinian style, the passage of a drug lead through to the market is a highly selective process where only the 'fittest' compounds will survive. Marine natural product leads will always be weighed at every step against synthetic products and leads from terrestrial sources. The scales to date have been biased against marine sources because of the economics and sustainability of the target compound supply and issues surrounding their legal provenance (Access and Benefit Sharing Agreements with source countries). Synthetic leads are clearly desirable on these counts, if they work. Marine leads, however, do work and many are highly specific in their activities because, as we have argued, they were designed expressly for relevant biological function.

The two major issues, supply and provenance, that have plagued marine natural products drug discovery over the last 30 years, have now been effectively resolved. Firstly most countries have established legal frameworks compliant with the Convention of Biological Diversity Guidelines for Access to Biodiversity and the fair and equitable benefit share of any revenue from successes. Secondly synthetic and semi-synthetic chemistry has evolved to a point where

supply is no longer an impassable hurdle. As indicated above, the future is likely to see metagenomic expression and manipulations as an increasingly common technique for lead development and supply into the market. We see an exciting future for marine natural products as drugs.

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Scuba divers' pulmonary oedema. A review

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Key words
Immersion, scuba diving, pulmonary oedema, review article

Abstract

(Edmonds C. Scuba divers' pulmonary oedema. A review. *Diving and Hyperbaric Medicine*. 2009;39(4):226-31.)
The literature on scuba divers' pulmonary oedema (SDPE) is reviewed, especially in its relationship to other immersion-induced pulmonary oedemas. It is concluded that although the three forms induced by swimming, freediving and scuba diving have some features in common, there are significant differences in their demographics, causation and clinical management. The swimming-induced cases tend to be young and fit, but exposed to excessive exertion. The freedivers experience extreme breath-holding and barotraumatic influences. The scuba divers are an older group and may have pre-existing or occult cardiovascular disease. Although the first-aid treatments may be similar, subsequent investigations and preventative measures will differ considerably

Introduction

Scuba divers' pulmonary oedema (SDPE) was first reported in 1981.[1] It is usually described as an uncommon disorder, only some dozens of cases being documented. Comprehensive reviews have been prepared by Lundgren and Miller, Slade et al and more recently by Koehle et al.[2–4] SDPE presents clinically with fast and shallow respirations, dyspnoea, fatigue, cough, sometimes with blood-stained expectoration, and auscultatory signs of pulmonary oedema; cyanosis may be present. Investigations reveal impaired spirometry and reduced pulmonary compliance, hypoxaemia and characteristic radiological (plain X-ray or CT scan) abnormalities.

There are both similarities and differences between terrestrial and immersion pulmonary oedemas. With differing causes and natural histories, extrapolation from the terrestrial to the diving situation may not be appropriate. Several, possibly distinct, forms of immersion pulmonary oedema (IPE) have been described: in swimmers, free (breath-hold) divers and scuba divers. This review attempts to distinguish between these but focuses mainly on SDPE and refers to the others where an association has been claimed.

Terrestrial pulmonary oedema

Pulmonary oedema is the accumulation of fluid in the lungs. It may be either a transudate (from high capillary-to-alveolar pressure gradients), an inflammatory exudate with protein, red cells, etc (capillary damage), or lymph accumulation.[5] It is well described in a variety of disorders in the general medical literature and may develop from both cardiogenic and non-cardiogenic causes. Cardiogenic pulmonary oedema is seen in myocardial infarction, cardiomyopathies, myocarditis, arrhythmias, hypertension, cardiac tamponade and acute fluid overload, etc. Non-cardiogenic pulmonary oedema may develop from a direct injury to the lung parenchyma as in thoracic surgical procedures, infections, allergies, toxic inhalants, trauma and aspiration, or be secondary to acute airway obstruction and other causes of negative inspiratory pressures – negative-pressure pulmonary oedema (NPPE) – or to neurogenic mechanisms.[5,6] Exertional pulmonary oedema has been reported both in athletes (long-distance running, rugby players) and race horses, whilst high-altitude pulmonary oedema occurs in climbers.[7,8] There is evidence that increased expiratory pressures (e.g., continuous positive airway pressure, CPAP) may ameliorate the effects of pulmonary oedema.[9]

Immersion pulmonary oedema

IPE was reviewed recently in 60 cases from the literature.[4] In this review, there were 34 scuba divers, 18 swimmers and eight freedivers. A prior or subsequent history of this disorder was present in at least 13 cases. The symptoms included cough in 82%, dyspnoea in 80% and haemoptysis in 62%. Less common were weakness and confusion; chest pain was not a feature. Although physical examination was not well described, crackles (rales) and wheezing were noted in 25% and 10% respectively. Most had the diagnosis verified radiologically. The mean oxygen partial pressure was 66.2 (SD 17.4) mmHg (8.82 +/- 2.32 kPa) with a mean arterial oxygen saturation (S_aO_2) of 88.8% (SD 7.3). In the majority, symptoms resolved within five minutes to 24 hours, but two cases were fatal. In the swimmers (Special Forces combat swimmers), heavy exertion was incriminated. A relationship between pulmonary oedema and 'thoracic squeeze' (pulmonary barotrauma of descent) was noted in the freedivers. Most of the swimmers and freedivers affected were otherwise healthy. Increased age was observed in the scuba divers with pulmonary oedema. As there are considerable differences in the epidemiology, aquatic behaviour and physiological stressors in each of these three groups, they are now considered separately.

Swimming-induced pulmonary oedema (SIPE)

Reports of dyspnoea and pulmonary congestion during surface swimming have often been associated with extreme exertion in both cold and warm (>20^{O}C) waters.[4,10–13] In a strenuous swimming time trial, eight of 30 young men were affected within the first 45 minutes, with a water temperature of 23^{O}C.[13] Over-hydration may have contributed, as they had all consumed 5 L of water prior to the swim to counter anticipated dehydration. The swimmers wore only bathing suits and fins and two had repeated episodes without the provocation of such extreme exercise and over-hydration.

In an Israeli military swimming fitness programme in water temperature of 19.6 (SD 3.2)^{O}C, 70 cases of SIPE were documented, all with dyspnoea combined with, in the majority, a productive cough, haemoptysis and 'inspiratory crackles'.[12] Chest pain or wheezing was noted in less than 9%. The mean S_aO_2 on air was 88.4% (SD 6.8) whilst spirometry demonstrated a temporary restrictive pattern. The chest radiography was normal after 12–18 hours. SIPE recurred in about a quarter of the swimmers. Over-hydration was not noted in this group.

An investigation of the S_aO_2 and spirometry findings in 29 incidents from 21 of 35 young men exposed to strenuous swimming over a two-month period, revealed similar changes, with a fall in S_aO_2 from 99% to 91%.[14] Forced expiratory volume in 1 sec (FEV_1), forced vital capacity (FVC) and the FEV_1/FVC ratio were all significantly lower in the SIPE group. Interestingly the pre-incident FVC and mid-expiratory flows (FEF_{25-75}) were lower in the swimmers who developed SIPE, and thus may be predictive of this disorder.

Explanations for SIPE include:
- increased cardiac output due to physical exertion;
- pulmonary vascular blood pooling due to immersion;
- increased pulmonary vascular resistance due to cold exposure;
- hydrostatic pressure effects;
- increased perfusion in the dependent lung with side-stroke swimming.[4,12,14,15]

The incidence of SIPE in Israeli combat swimmers, swimming vigorously, was 20 per year, up until 2004.[16] A comprehensive pulmonary investigation, including broncho-alveolar lavage, was undertaken in five such SIPE cases, and the results indicated that the pathology was capillary stress failure, with no evidence of inflammation. FVC and FEV_1 were reduced in two of these cases, but information on the delay between the incident and the investigations was lacking.

The common feature, pathophysiologically, was thought to be capillary stress and failure resulting from exertion and an increased inspiratory load, with the hydrostatic effects of immersion superimposed. The lateral decubitus swimming position (sidestroke) aggravated these effects in the dependent lung. Not all cases of SIPE exercised excessively. Some, especially the older subjects, may have had a cardiac basis, as with SDPE (see below).

Freediving, pulmonary oedema and pulmonary barotrauma of descent

Breath-hold dives to a depth of over 200 metres have been achieved in recent times, through a combination of physiological and anatomical factors and responses and of modern diving techniques. Pulmonary oedema in breath-hold diving has been reported and is believed to be largely a manifestation of pulmonary barotrauma of descent, 'lung squeeze', due to the reduction of lung volume below the residual volume developing according to Boyle's Law.[2,4,17,18] The postulated explanations for pulmonary oedema with freediving include:
- negative intra-alveolar pressure gradients due to descent
- pulmonary vascular blood pooling due to immersion
- increased pulmonary vascular pressure due to cold exposure
- increased cardiac output due to physical exertion
- pulmonary trauma due to 'lung packing'.

Clinical features of this pulmonary barotrauma are poorly documented but may include chest pain and haemoptysis with haemorrhagic pulmonary oedema. Treatment is based on the general principles of resuscitation, with 100% oxygen, treatment of shock, fluid replacement and CPAP. Two breath-hold fatalities attributed to pulmonary oedema have been reported.[4]

Liner and Andersson investigated 19 deep breath-hold divers during an international competition, to elicit signs of pulmonary oedema that were not evident following shallow dives.[18] After diving to 25–75 msw, 12 divers had such signs. The mean reductions in FVC and FEV_1 were -9% and -12% respectively, and -4% for S_aO_2. Six of the divers had respiratory symptoms (dyspnoea, cough, fatigue, retrosternal chest pain or discomfort and haemoptysis) and, in these, the falls in FVC, FEV_1 and S_aO_2 were greater: -16%, -27% and -11% respectively.

Scuba divers' pulmonary oedema (SDPE)

SDPE is usually described as an uncommon disorder, often in apparently healthy individuals with only a few dozen cases being documented.[4,11,15,19] In a survey of 1,250 divers, of the 460 responders, five (1.1%) had a history suggestive of pulmonary oedema.[11] The actual incidence is unknown, but SDPE is probably under diagnosed.[3,19,20] It differs from the other IPEs in being more frequent in older divers (see below). Exertion is not often recorded and is sometimes specifically denied.[15,20–22]

Symptoms usually resolve rapidly (minutes or hours) after the immersion. The hypoxaemia, respiratory function and radiology (chest X-ray or CT scan) also resolve rapidly in most cases.[11,19,23,24] Two deaths have been reported: one in a diver (who had had a previous episode) with hypertension, dyslipidaemia and arteriopathy, the other having no cardiac abnormality.[19] However, other deaths could have occurred and be attributed to drowning. Treatment includes oxygen supplementation, positive pressure respiration and possibly diuretics.

An individual predisposition for pulmonary oedema is a likely factor since a diver or swimmer with pulmonary oedema may have other episodes of IPE, previously or subsequently.[1,3,4,10,11,19–21,25] Yet when diving under similar conditions, the diver may have been spared. Whether the variation in presentation relates to the individual diver, the dive profile, environmental conditions or the dive equipment is unknown.

Discussion

Various conjectures on the aetiology of SDPE have been put forward.

COLD-INDUCED HYPERTENSIVE PULMONARY OEDEMA

Wilmshurst et al first described SDPE and attributed it mainly to the effects of cold, inducing hypertensive pulmonary oedema.[1] In their series, cardiovascular abnormalities were present in those who developed this condition on one or more occasions, compared to divers who never had pulmonary oedema. In a further report comparing divers and swimmers who had IPE to controls, it was hypothesized that 'labile hypertensives' with an exaggerated vasoconstrictor response to cold and/or raised oxygen pressure would be particularly prone to develop pulmonary oedema as a result of an increase in after-load because of systemic vasoconstriction, and a pre-load stress from the pulmonary vascular blood volume increase that occurs with immersion.[10] The divers in the pulmonary oedema group were followed up for an average of eight years, at which time seven had become hypertensive. All the cases occurred in waters below 12^{O}C. Thus, Wilmshurst's hypothesis incriminated a vascular hyper-reactivity to a cold stimulus.

This explanation is supported in some reports,[1,10,19,25] but not others, in which SDPE has been reported in relatively warm or tropical waters.[3,11,20–23] Hampson and Dunford concluded that cold may not have been an important factor in some of their other cases because the divers were protected by insulating drysuits, although they were still presumably exposed to cold-air inhalation.[15] They suggested that individuals with SDPE should be advised to forgo scuba diving. Pons et al reported results which did not support Wilmshurst's observations, finding no differences in forearm vascular resistance, vasoactive hormone levels, and left ventricular function between SDPE subjects and healthy controls.[11]

IMMERSION-INDUCED INTRATHORACIC BLOOD POOLING

Intrathoracic blood pooling can be induced when the body is submerged.[2,3,10,24,26] Some report an increase of up to 700 ml of pulmonary blood in water of 33–35^{O}C, with a 13–21 mmHg increase in pulmonary arteriole transmural pressure and a reduction in vital capacity of 5–10% in warm and cold waters respectively.[24,26] Others have observed smaller volumes of blood pooling, of up to 221 ml.[26,27] The thoracic blood pooling and the raised pulmonary artery pressure are postulated to cause increased capillary permeability, leading to pulmonary oedema.[4,10] Some feel that this is not a likely explanation for the development of this form of oedema.[11] An argument given is that the symptoms typically resolve rapidly once the diver is out of the water. However, many case histories include expectoration of bloody froth, indicating pulmonary capillary damage.[3,11,19,20]

AGE

Advanced age is a predisposing factor according to most authors.[4,10,19,20,23,24] Referencing the literature, Hampson and Dunford cite the age of 20 divers with SDPE from three studies to have been, on average, 42.7 (SD 2.7) years, while a large group of divers with other diving injuries averaged 35.5 (SD 4.0) years.[15] Cochard et al reviewed 37 cases and calculated the mean age of SDPE to be 50.3 (SD 7.5) years, compared to a mean age of other diving-related injuries of 34.0 (SD 9.2) years.[19] The detrimental effects of age could be enhanced by its correlation with hypertension, ischaemic or other heart diseases and impaired respiratory function. Koehle et al compared the demographics of scuba divers in Australia with their SDPE cases. The male/female ratios were almost the same but there were few divers over 45 years old in the diving population, whereas over half the SDPE cases were over this age.[4] This contrasted with the other IPEs.

NEGATIVE-PRESSURE PULMONARY OEDEMA

Negative inspiratory pressure has been postulated as a cause of SDPE by most reviewers.[2,3,11,19] In the scuba-diving environment, negative intrathoracic pressures during inspiration could occur from:

- immersion per se, especially with a head-up/vertical or head-out position;
- inspiratory breathing resistance from diving equipment;
- reduced gas supply/pressure;
- excessive gas density with depth;
- increased ventilation, as occurs with high workloads and anxiety;

- the use of a rebreather device with the counter-lung positioned at a shallower depth than the lung centroid.

Pulmonary oedema has not usually been reported in the numerous 'head-out' immersion experiments in the literature. There were some effects on lung function from head-out immersion in young men, when this was combined with a mild negative inspiratory pressure of 9 cmH_2O.[26] In the absence of clinical symptoms, and with the failure to reduce either FVC or maximal expiratory flows, this contribution to pulmonary oedema is unconvincing. In an ongoing study, this disorder was not provoked when divers were subjected to considerable negative-pressure inspiration, even when the negative pressures induced were extreme and close to intolerable over a one-hour period (Shields S, personal communication, 2009).

Thorsen et al demonstrated that increasing the inspiratory resistive load in divers and subjecting them to head-out immersion, reduced the diffusing capacity of the lung.[26] This may have indicated a subclinical pulmonary oedema. No changes occurred in pulmonary function with either of the conditions separately. There were no changes in FVC or maximal expiratory flows. Pulmonary oedema was not noted in experimental and actual head-out immersion experiences recorded in the literature.

The maximum negative inspiratory pressure likely to be encountered from a scuba-air breathing apparatus is 25–32 cmH_2O.[2] In the diving literature, 15–20 cmH_2O inspiratory resistance is considered moderate and 20–25 cmH_2O high.[27] The maximum sustained inspiratory load that can be tolerated is about 75 cmH_2O.[28] As quoted by Lundgren, even short exposures to 100 cmH_2O (as in attempting to snorkel at 1 metre depth) resulted in ventricular extrasystoles in three out of five subjects.[2] Acute cardiac dilatation results from greater exposures. A temporary increase in heart size was observed by Risch et al during submersion and negative-pressure breathing.[29]

PRE-EXISTING CARDIAC DISORDER

Magder et al compared the different clinical manifestations of myocardial ischaemia induced by exercise in the terrestrial and aquatic environments.[30] In these experiments, middle-aged males with cardiac ischaemia were exercised in both environments, with electrocardiographic monitoring to detect ST depression. Clinically the cardiac ischaemia presented with dyspnoea in the water (both 18^{O}C and 25.5^{O}C), and with angina pectoris on land. This may well have been the first description of mild pulmonary oedema when swimming, and whilst under rigorous scientific observation. The recognition of dyspnoea as a manifestation of ischaemic heart disease while immersed is, thus, understandable, as is the alleviation of this symptom following successful coronary artery surgery.[21,23,31]

Cochard et al described six episodes of SDPE amongst five experienced divers, aged 37–56, three of whom had hypertension, one had cardiac ischaemia with ventricular dysfunction and one died after a cardiac arrest.[19] Garcia et al described 10 cases, aged 46–74 years old, who developed pulmonary oedema, all of whom had cardiovascular disease.[32] SDPE developed in five prior to surfacing. Eight divers were taking beta-blockers, and this association has been noted in other case histories, as has the relationship with hypertension.[22,23,,32,33] Other cardiac pathologies, such as cardiomyopathy, have been reported in association with SDPE.[20]

The association of SDPE with hypertension is confused by other factors such as age, beta-blocker medication and ischaemic heart disease, complicating understanding of the relative significance of each of these factors.[4,32,33] Thus, SDPE, especially in older divers, should be an indication for comprehensive cardiac investigation, not only for possible cardiovascular therapy but also to avoid further SDPE episodes. It seems reasonable that unless the cause can be identified, verified and corrected, divers with SDPE should be advised of the possible risks of continuing with the activity that provoked it, and against further diving or energetic swimming.

DIVING-RELATED DISEASES

Pulmonary oedema may develop in diving, as it does in the terrestrial environment, from a variety of disorders and these complicate the diagnosis of SDPE. Some of these may be related to the diving activity and are more fully described in the diving medical texts.[34] Near drowning is recognised as a common cause of pulmonary oedema. A 'salt-water aspiration syndrome' (SWAS), secondary to inhalation of a fine spray of seawater through the diving regulator, was first described in 1970.[35] The clinical manifestations, time course and underlying mechanism(s) of SWAS, as verified experimentally, are different to those of SDPE.[35] Similar but more gross effects are observed in near-drowning cases.[36] Other pulmonary diseases to which divers are exposed may produce pulmonary oedema, or dyspnoea that could be attributed to pulmonary oedema.[34] These may include respiratory oxygen toxicity, gas contaminations, cold urticaria and asthma. Pulmonary decompression sickness, pulmonary barotrauma and the so-called 'deep diving dyspnoea' are diving disorders that may cause diagnostic confusion with uncomplicated SDPE.

To date, no association has been demonstrated between SDPE and decompression effects, although symptoms of both usually occur on or soon after ascent. Some SDPEs develop in such shallow exposures that intravascular bubble formation is unlikely.[20,22,33] Pulmonary filtration of bubbles during decompression in deeper scuba diving may increase pulmonary hypertension and damage capillary integrity, thereby increasing the likelihood of pulmonary oedema.

EXERCISE

The relationship between severe exertion and pulmonary oedema has been demonstrated in rugby players, cyclists, marathon runners and racehorses. West states "*Pulmonary capillaries have a dilemma. Their walls must be extremely thin for efficient gas exchange, but be immensely strong to resist the mechanical stresses that develop during heavy exercise. Elite human athletes at maximal exercise develop changes in the structure of the capillary wall as evidenced by red blood cells (and protein) in their alveoli. Racehorses routinely break their pulmonary capillaries while galloping.*"[8] Wagner et al indicated that the high cardiac output associated with high-intensity exercise elevates the pulmonary vascular pressure to such a degree that transudation of fluid across the capillary endothelium into the interstitial tissue increases markedly.[37,38]

Zavorsky, in 2007, reviewed the general medical literature, and supported the observation that exercise provoked pulmonary oedema.[39] His studies involved 137 exercising subjects and he grouped these into three: a short exercise stress that reached maximal oxygen consumption for only a couple of minutes; a prolonged (15–120 min) submaximal exercise and a maximum or near-maximum strenuous, sustained effort. Evidence of pulmonary oedema was found in 0%, 16% and 65% of subjects respectively. The likelihood seemed independent of lung size, sex or aerobic fitness. Thus, he supported a simple dose-response relationship between strenuous exercise and pulmonary oedema.

It is possible that negative inspiratory pressure and increased resistance to inspiration during maximal ventilation may occur with strenuous swimming. The association between extreme exercise and SIPE has been well documented, but a relationship with SDPE has not. Most cases of SDPE were not exerting themselves, given the exercise required for normal scuba activities. Because of the increased age and possibly dubious cardiac status in SDPE cases, it is feasible that a lesser degree of exercise may have more pronounced effects. For this reason, the influence of exercise on SDPE awaits further clarification.

MULTIFACTORIAL

Most would agree with Cochard that the explanation for SDPE is most likely in the combination of immersion, cold and compressed-air breathing stresses imposed on the cardiovascular and respiratory systems.[19] However, explanation of SDPE by applying the known physiological stressors from the diving environment is based on assumptions that need validation. For example, a deleterious influence of tight wetsuits has been mentioned, but was not confirmed in one experiment.[40] Such a restriction to respiration may be more likely to increase the work of breathing, thus possibly increasing dyspnoea in cases of SDPE, rather than contributing to the disease itself. Most other causation hypotheses have yet to be validated.

Conclusions

It is proposed that there are three major forms of IPE that occur in surface swimmers, freedivers and scuba divers. It is important to distinguish between these, even though they appear to share provoking causes to very varying degrees. In some instances, observations from the general medical literature enhance our understanding of the possible aetiologies, but often IPE has specific stressors.

The mechanisms of SIPE appear to include severe exertion and immersion, including thoracic blood pooling and the hydrostatic effects on the pulmonary circulation.

Pulmonary oedema in freediving is explained by the barotraumatic effects of descent. Both exercise and pulmonary volutrauma may contribute in some cases.

Existing cardiovascular and diving-induced diseases may cause or contribute to SDPE. The effects of immersion, including the increase in pulmonary vascular blood volume, the vascular response to hypothermia, the negative hydrostatic pressures of head-out and vertical positioning and negative intra-pleural pressures generated from exercise, gas density and inadequate diving equipment all appear to be contributory to SDPE. A full understanding of the mechanisms whereby these interact in individual divers to precipitate SDPE awaits clarification.

Acknowledgements

Without the critical appraisal and constructive suggestions of John Pennefather, Scientific Officer of the Royal Australian Navy Submarine and Underwater Medicine Unit, this review would never have been possible. The assistance from the medical staff at the SUMU, and use of the library facilities, are also much appreciated.

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Editor's note:
The following brief case report of a scuba diver with acute-onset dyspnoea at the end of a dive is typical of some of the presentations of SDPE. Here, a well-informed diver self-diagnoses SDPE and takes preventative action. Whether his diagnosis was correct or not is left to the reader to decide.

The diving doctor's diary

Scuba divers' pulmonary oedema. A case report

Carl Edmonds

Key words
Immersion, scuba diving, pulmonary oedema, case reports

Abstract

(Edmonds C. Scuba divers' pulmonary oedema. A case report. *Diving and Hyperbaric Medicine*. 2009;39(4):232-3.)
A case of presumed scuba divers' pulmonary oedema (SDPE) is presented. The symptomatology and clinical progress is typical and it illustrates some of the aetiological factors incriminated in this disease, as well as measures taken to avoid the disorder. Such factors include the effects of immersion, negative-pressure inspiration induced by vertical positioning in the water, resistance to breathing by the scuba regulator and advanced age. Dyspnoea may have been exacerbated by the respiratory restriction imposed by the diving equipment. Other aetiological factors not relevant to this case are mentioned, as is the possible differential diagnosis. An accompanying review article discusses SDPE in greater detail.

Introduction

The following is a fairly typical case history of scuba divers' pulmonary oedema (SDPE) that illustrates the difficulty facing a diver who must act on the proposed theoretical mechanisms. Unfortunately, these are mainly speculative and there is little direct experimental evidence that any one specific characteristic of scuba diving is responsible for the pulmonary oedema observed.[1]

Case history

On the first dive of the second diving day, a 72-year-old experienced diver surfaced from a dive to a maximum depth of 15 metres' sea water (msw) for a duration of 50 minutes, with an extra five minutes at a 3–5 metre decompression safety stop. Water temperature was 27^{O}C and there was only a slight current. There was no rapid ascent, no salt-water aspiration or other dive incident. It was an innocuous dive, without any excessive exertion. During the safety stop he noticed increasing dyspnoea, but attributed this to a low-on-air situation, having only 40 bar remaining.

He was at the surface in a head-out vertical position for about 10 minutes, during which time he had inflated his buoyancy compensator (BCD). During that time, he noted increasing difficulty in obtaining sufficient air from his demand valve and snorkel. He also observed the sound of fluid in his lungs (rattling breathing). He attempted to relieve the dyspnoea by pulling on the neck of his tight wetsuit, without effect. Dyspnoea, fatigue, the moist breath sounds, cough and expectoration continued after he boarded the dive vessel, and then in a diminishing manner for the next 2–3 hours, all aggravated by exertion.

When diving on the preceding day, he had complained to the dive organiser that there was resistance to breathing from the main demand valve at 18 msw. He had also tried to exchange the wetsuit for one that fitted him better, but none was available. On commencing the first dive of the second day, it was evident that the hired demand valve had not been repaired or replaced, and this breathing resistance was again noted.

After a 4–5 hour surface interval, he felt normal and so dived again on an almost identical profile, but without any incident or difficulty. For this second dive he dispensed with the tight wetsuit (hired) and rejected the primary demand valve for the one on his octopus rig (also hired). This regulator produced no excessive resistance to breathing. On surfacing, he assumed a horizontal position and breathed through his snorkel.

The diver deduced that his dyspnoea was related to breathing against an appreciable resistance (negative-pressure inspiration), vertical position at the safety stop and during his head-out immersion after surfacing. It was possibly aggravated by his tight wetsuit. He also wondered if the inflated buoyancy compensator had been contributory.

Discussion

In this case, as in many similar reported cases, there was no immediate medical investigation of the incident to verify the diagnosis, but the clinical manifestations were indicative of SDPE. The vertical or head-out immersion position could have contributed to a fluid shift of blood into the lungs and the tight wetsuit and inflated buoyancy compensator could have accentuated the work of breathing by decreasing chest-wall compliance. These factors were all avoided on the second dive by changing regulators, not wearing the wetsuit, not over-inflating the buoyancy compensator and swimming horizontally after surfacing.

Specifically, in this case the dyspnoea seemed *not* to be related to:

- cold exposure (warm water, wetsuit);
- hypertension (normotensive, BP 125/80);
- ischaemic heart disease (maximal stress ECG a month before the incident was normal, and no symptomatology developed afterwards);
- salt-water aspiration (this did not occur);
- asthma (no clinical or spirometric indication);
- excessive depth (symptoms first noted near and on the surface).

There was no other evidence of decompression sickness, and the dives were well within no-decompression limits.

Pulmonary oedema in divers has been reported in the literature since 1981.[2] Though uncommon, it is probably under-reported because it typically resolves rapidly once the diver emerges from the water, as in this diver, and death is only rarely reported. Although it may occur in apparently healthy young divers, it is more frequent in older divers and tends to be recurrent. Clinical presentation includes dyspnoea, fatigue, cough and expectoration, sometimes blood-stained, with hypoxia and auscultatory and radiological signs of pulmonary oedema.

The proposed mechanisms encompass both cardiac and non-cardiac aetiologies. The cardiac causes include physiological changes in both myocardial pre-load and after-load with immersion and the presence of cardiac ischaemia. Non-cardiac causes include changes in pulmonary physiology and equipment-related limitations. Other diving-related conditions such as salt-water aspiration, near drowning, respiratory oxygen toxicity and gas contamination may induce an inflammatory exudate that may present as pulmonary oedema – more protracted than the transudates. Pulmonary decompression sickness and pulmonary barotraumas are diving disorders that may cause diagnostic confusion with other pulmonary oedemas. These various factors in the aetiology of SDPE are discussed in detail in the accompanying review paper.[1]

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The poetry doctor

Radical thoughts

I am an oxygen radical,
A rebel molecule,
With a negative attitude
To disobey the rules.

Electrically I am unpaired,
Marriage ain't for me.
A single electron fully bared
I'll always wander free.

I'm symbolized by a dot
Implying I'm a blob
But don't think I'm running on the spot
For I'm manic on the job.

People think that I am mad
Because I am unstable
But my reactivity
Is my species label.

I can do astounding things,
A "superoxide" God,
Invincible to everything
Except that enzyme SOD!

Because of this I've had bad press
That's caused much angst and raging
Stating that I am the cause
Of cancer and of aging.

These are lies to scare you all
To doubt longevity
So you'll take huge doses of
Vitamins E and C.

I even help defend you
And aid phagocytosis.
My actions are very sane
Not driven by psychosis.

So don't be fooled by all the spin
That I offend with stealth.
I am conservative deep within
And essential for good health.

John Parker
<*www.thepoetrydoctor.com*>

The world as it is

British Sub-Aqua Club diving incidents report 2008

Compiled by Brian Cumming, Diving Incidents Advisor
<http://www.bsac.com/page.asp?section=1038&sectionTitle=Annual+Diving+Incident+Report>

Summary of the 2008 report prepared by Colin Wilson

The British Sub-Aqua Club (BSAC) has been collecting and analysing diving incidents reported to them by their membership, and from other sources available to them, for nearly 30 years. Brian Cumming has been the coordinator and analyser of the data for a number of years. Summaries of the years 2005, 2006 and 2007 have been previously published in this journal and the full reports from the years 1980 to 2008 are readily available.[1–5] The data collection and analysis methods used have been described previously.[1–3] There are limitations to the completeness of the data, though it is reasonable to accept the number of fatalities recorded as accurate. The decompression incident reports will likely exclude patients avoiding emergency services and directly referring themselves to recompression facilities.

There were 359 reports for 2008, similar to 2007 and below the average of over 400 in the early years of this decade. Understandably 72% of the reports occur in the northern hemisphere summer. Ascent incidents have seen a worrying increase over the years, with the BSAC running a campaign to encourage divers to pay more attention to buoyancy. The results are seen this year with a 30% reduction in 2008. Depths ranged from the surface to greater than 50 metres' sea water (msw). This summary focuses on the fatalities and cases of decompression illness (DCI) in the report.

Fatalities

There were ten fatalities recorded; fewer than in previous years and below the average of 17.3 for the last decade. There was usually more than one major factor associated with each fatality:

- one case involved a diver thought to have suffered a heart attack; in two other cases it seems very likely that an acute medical problem was the root cause;
- six cases involved a separation of some kind:
  - a diver was lost in low visibility inside a wreck;
  - two divers became separated from their buddies during the ascent phase of the dive;
  - one snorkel diver in difficulties became separated from his buddy;
  - one diver was found unconscious underwater; the preceding events are currently not known;
  - a diver elected to leave his buddy and to rest on some rocks after surfacing from a dive.
- two divers were using rebreathers and, while the role of the rebreather in the incident is not clear, problems with or misuse of the system cannot be ruled out;
- one diver was trapped in a wreck and ran out of air;
- two cases involved three people diving together and in both these cases an underwater separation occurred when problems arose during the ascent;
- one diver made a buoyant ascent because of items that he was carrying pressing on his drysuit inflation valve.

The descriptions of events, although not as comprehensive as those reported from Australia, are valuable in pointing out errors and lessons to be learnt.[6]

From the fatalities section:

Case 1

"Three divers descended to a wreck which lay down a slope. At 24 msw the conditions were good and the three agreed to continue to move down the wreck. At 47 msw one of the three signalled that they should start to make their way back up the wreck. As they turned, they stirred up silt and the visibility reduced. Then one of the divers signalled that he was unhappy and wanted to ascend. At this point another of the divers felt his weightbelt slip, they stirred up more silt and the third diver moved away slightly to get into clearer water. The diver whose weightbelt had slipped then lost the belt completely and he made a buoyant ascent to the surface. At no time during this ascent did he see either of the other divers. The third diver who had moved back out of the silt saw two torches ascending and assumed that the second diver had taken the diver who had signalled for an ascent to the surface. The third diver followed the wreck back upwards and surfaced after...21 min...about 5 min after the buoyant diver had surfaced. The diver who had signalled that he wanted to ascend did not return to the surface. The other two divers both assumed that he was with the other one. Another two divers entered the water and conducted a search of the shallow end of the wreck but they found no trace of the missing diver. The Coastguard was alerted and an extensive...search...[found] *no trace of the missing diver."*

Case 2

"A group of divers conduct[ed] *a drift dive to gather scallops in a maximum depth of 24 msw...One pair of divers collected a lot of scallops which they retained in bags. One of the divers then found a cannon ball which he sent to the surface under a lifting bag. The second diver also found a cannon ball which he tried to put in his scallop bag. The first diver then passed him another bag for the cannon ball and expected him to fasten it to his lifting bag and send it to the surface but the second diver did not do this. Instead he continued the dive holding on to the cannon ball in the bag. The first diver again prompted him to lift the cannon ball but he declined. About 5 min later the diver with the cannon ball signalled that they should ascend. The first diver then looked down to fasten his scallop bag to his weightbelt and to reel in*

the SMB line. When he looked back the diver with the cannon ball had gone. He conducted a brief search...then started his ascent with his computer indicating a total ascent duration, including stops, of 11 min. He made his first decompression stop at about 5 msw. At this point he looked up and saw his buddy at the surface looking down at him. He signalled him to re-descend to join him to conduct his decompression stops but he didn't. He saw that the diver had the scallop and cannon ball bags clipped to a D ring on his chest. He swam up to the diver at a depth of about 2 msw and attempted to pull him down, but he could not do so...He tried twice, then the SMB line was cut and he thought that his buddy was resolving the problem. The [first] *diver then sank rapidly and struggled to regain the correct depth. A boat passed over his head and the propeller just missed him. He returned to about 6 msw and completed a 15 min decompression stop. There was a lot of boat traffic so he waited a further minute before surfacing. He was recovered into another boat. The diver who had surfaced with the scallops and cannon ball was seen by those in his boat floating face down. They shouted at him but got no response. The boat approached him and one of the party re-entered the water to assist the troubled diver. The rescuing diver attempted to turn him into a face up position but could not do so. The diver was brought to the...boat where...*[he] *was not conscious and resuscitation techniques were applied. The Coastguard was alerted and the casualty was airlifted to hospital where he was declared dead. It was subsequently found that the casualty had not taken his lifting bag on the dive with him. The cause of death was diffuse gas embolism due to pulmonary barotrauma. Media reporting of an inquest reported findings that the diver had made a rapid ascent as a result of the bags that he was carrying pressing on his drysuit inflation valve and causing him to lose control of his buoyancy."*

Decompression incidents

There has been an increase in decompression illness (DCI), with this not only being the largest category, with 125 incident reports, but 50% more than the 81 in 2007 (though less than the peak of 144 in 2002). Some reports refer to multiple divers, which gives a total of 132 cases of DCI. The major causal factors associated with these incidents were:

- 44 involved repetitive diving;
- 38 involved rapid ascents;
- 23 involved diving to deeper than 30 msw;
- 15 involved missed decompression stops;
- some cases involved more than one of these causes.

There were also a number of reports from the RNLI of undefined "*diver illness*" some of which may have been DCI; these numbers were similar to previous years.

From the DCI section:

Case 3

"A diver conducted a 33 min dive to a maximum depth of 38 msw with a 1 min stop at 20 msw and a 5 min stop at 6m during her ascent. When the boat approached to pick her up she was unable to grasp the ladder and she seemed unresponsive and unable to help herself. Other divers removed her kit and lifted her into the boat. She was placed on oxygen and given fluids and the Coastguard was alerted. She complained of a slight tingling in her legs and feet. She was transferred into a lifeboat and then airlifted to a recompression facility where she received a precautionary treatment. The diver had had a suspected DCI four years previously and a PFO had been diagnosed and closed."

Case 4

"A diver conducted a dive to 64 msw using trimix 17/35 with nitrox 40 and 100% oxygen used during decompression stops. His total dive duration was 110 min. After this dive he experienced a tightness in his left arm and shoulder. The following day he dived to 65 msw for a total of about 120 min. His ascent profile was as follows: 65 msw to 30 msw, 6 min on trimix; 30 msw to 9 msw, 24 min on nitrox 40; 9 msw to 6 msw, 44 min on oxygen; then he surfaced. During this ascent, at a depth of 15 msw, he noticed an itching across his shoulders and a tightening in his left arm and chest. On surfacing the itching spread and he developed an ache in his left arm, shoulder, chest and upper legs. The Coastguard was alerted and the diver was airlifted to a recompression facility for treatment. The diver had been treated for DCI the previous year and had had symptoms of skin DCI and swelling after a number of previous dives..."

As in previous reports, there are common errors oft repeated. This should not detract from the lessons to be learned. Brian Cumming and the BSAC team's efforts in producing these reports are commended and should be digested by all divers, diver educators and diving physicians.

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Book review

Medicine for the outdoors

The essential guide to first aid and medical emergencies, 5th edition

Paul S Auerbach

Soft cover, 553 pages
ISBN 978-0-323-06813-0
Mosby Elsevier; 2009
Available direct from the publisher:
<www.elsevierhealth.com>
Price: Aus$35.10, EUR€22.99

"*The outdoor environment is beautiful, but is ever changing*" and in light of this and advances in medical knowledge and suggestions from readers, Paul Auerbach, the world guru on wilderness medicine, has produced this, the fifth edition of *Medicine for the Outdoors*. Auerbach has many accolades and besides being professor of both surgery and emergency medicine at Stanford University, he is also Editor of *Wilderness Medicine* and is widely published and respected in his field. The quotes from the inside cover make amusing reading: "*This book is your wilderness 911*" and "*…gold standard for health and safety outdoors*". But it gets better, "*Auerbach is to wilderness medicine what Bill Gates is to computers*" and finally "*…a must-have medical manual for serious travellers who venture off the beaten track*".

The introduction tells us that the purpose of this book is to provide the reader with brief explanations of a wide variety of medical problems and to offer practical solutions. It assumes a basic understanding of how the body works and is written as a "*ready reference for a layperson who needs to medically rescue or aid an ill or injured victim*". It emphasises, however, that it does not transform a layperson into a physician and "*the recommendations should not be considered substitutes for prompt evaluation by a trained medical professional*".

The book is divided into five clearly defined parts. Part 1 covers general information outlining how to use the book, preparation and general first aid. Part 2 deals with the major medical problems, including an ABCD approach to the unconscious patient, and provides notes on everything from chest injury to burns to emergency childbirth. Part 3 covers minor medical problems including eye, skin and male genital problems. Part 4 outlines disorders related to specific environments including cold, fire and animal attacks, and finally Part 5 contains miscellaneous information covering topics like oxygen administration, transport of victims and immunization. There are details of extremely comprehensive first-aid kits, good diagrams of toxic plants and a brief procedures section including how to remove fish hooks. The appendices include drug lists, a useful glossary and conversion tables.

Relevant to diving medicine, there are a few well-written and understandable pages on diving accidents and drowning. These deal with air embolism, decompression illness and notes on ENT barotrauma, including why it happens and what to do. The advice on drowning management, likewise, is methodical and practical.

Topics are easy to find and suitably comprehensive for the purposes of this book and illustrations are clear and add value, in particular those on bandaging, suturing and joint relocation techniques. The book's size would allow it to be easily slipped into a backpack and carried into the wilderness. The book has limitations, though, and is not designed for a physician with sophisticated equipment. Generally the advice is sound and evidence based and I found the section on hypothermia very useful until I came to the part where the author suggested that the reader might blow warm air from an electric hairdryer into the sleeping bag with the victim! Our wilderness must be different!

All in all, an easy read with lots of useful advice but I did wonder if perhaps there was sometimes enough information to make the layman dangerous: the first-aid kits and medication lists are more comprehensive than those in my emergency department!

Sandy Inglis, Consultant in emergency medicine and hyperbaric medicine, Christchurch Hospital, New Zealand

Key words
First aid, general interest, book reviews

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Minutes of the EUBS Executive Committee Meeting, Aberdeen, 30 August 2009

Present: AO Brubakk, P Germonpré, N Bitterman, J Schmutz, P Knessl, P Müller, P Wooding

Apologies: P Bryson, M Cimsit
Invited: J Ross (unable to attend)

1. Minutes of ExCom Meeting 2008 (Graz):
Accepted

2. Report from Secretary General EUBS Meeting 2009
No information; Dr Ross could not attend.

3. Travel grant:
3.1 Two applications were received, one was withdrawn due to personal reasons, one was accepted.
3.2 The awardee will be encouraged to submit his mini-paper to the Editor of DHM for peer review and possible publication in the Journal.
3.3 Discussion re the necessity for applicants to produce a mini-paper instead of just an abstract: it was decided to keep up this rule as a sort of 'quality control' and to facilitate later submission to DHM.

4. Zetterström Committee:
4.1 Committee Members: J Schmutz, P Müller, S Watt (local scientific committee)
4.2 Poster submissions can compete only if they have not been published or submitted elsewhere; the final paper should be submitted within 12 months to DHM for peer review.

5. Executive Committee renewal:
5.1 Maide Cimsit is leaving the Committee this year after her three-year term as Member-at-Large. The ExCom wishes to thank her, unfortunately she cannot be present.
5.2 Ballots for Vice-President and Member-at-Large 2009:
only 84 votes out of 299 members (28%) were received, there were 4 abstentions
the cost of paper voting is about £300 excluding secretarial work
Vice-President: one candidate, elected: C. Balestra
Member-at-Large: two candidates, elected: Andreas Möllerlökken
5.3 Next year, votes will hopefully be done electronically, this will reduce costs and hopefully increase the number of voters. In 2007, a preliminary test showed that this was feasible. The EUBS Constitution was changed in 2008 to allow electronic voting.

6. DHM Journal (P Müller)
6.1 Advertising policy: a transparent advertisement policy has been proposed by the DHM Editorial Board. Accepted. The issue of free advertising for not-for-profit institutions is discussed; EUBS ExCom will enquire about this to the SPUMS Committee.
6.2 Starting from the September issue, a regular CME article will be published (initiative: M. Bennett). Starting from a case report or series, CME questions will be presented; answers can be mailed to the author or DHM Editor and with the 'points', a CME certificate will be issued. Volunteers are wanted to provide regular articles for this.
6.3 At least a few copies of the Proceedings of future Annual Scientific Meetings (ASM) of EUBS should be sent to DHM Editorial Office, for prospection of possible contributions to the Journal (pending peer review). A proposal has been received from the Editor and European Editor – this is accepted by ExCom.
6.4 The Memorandum for Future Secretary Generals, a document drafted in 1993 by H Ornhagen and over the years adapted and refined, will be finalised by P Germonpré and submitted to ExCom for approval. it will incorporate these new elements re DHM.
6.5 A letter of intention has been received from the South African Undersea and Hyperbaric Medicine Association (SAUHMA) expressing interest in the DHM Journal. It is at this time not entirely clear what the expectations and intentions are. ExCom will liaise with SPUMS Committee to further define this issue.
6.6 The DHM Editors wish to attend each Society's ASM. This is deemed useful, as face-to-face contacts are needed occasionally – ASMs are a good place to combine this with the search for new 'material' for the Journal. The costs of travel for the Editors should be incorporated into the production costs of the Journal, not carried by the EUBS. It is up to the local Secretary General to possibly waive the registration fee – a recommendation will be made in this sense.

7. Website (Peter Germonpré PG)
7.1 Electronic payment using PayPal: 106 renewals via the website which is safe and convenient, better than credit card machine; however, certain countries like Egypt are excluded. These problems can be solved by direct contact with PG.
7.2 Some technical problems mostly due to security settings of user's computer. People should contact PG or T Wooding in case of trouble.
7.3 Proposition to implement on homepage :
New members (every 3 months?): not unanimously backed by ExCom.
In view of EBM requirements PG will create a page informing about investigator recruitment in ongoing clinical studies (HOPON, HOLTT, etc).
An educational page informing on courses, congresses etc for physicians, nurses, technicians etc: Input needed from ExCom and members.

8. Finances (Tricia Wooding)
8.1 Due to the increased costs of producing the Journal since the merger with DHM in January 2008, and because

the increase in membership fee was only effectively executed since September 2008, EUBS has been forced to find temporary financial means during the months of April–June 2009. A short-term interest-free loan from the British Hyperbaric Association (BHA) of £2,000 has been obtained and has been paid back. The ExCom wishes to express their thanks to BHA for helping out.

8.2 Membership: EUBS currently has 299 members, 30 new members since January 2009.

8.3 Corporate Membership: ExCom should find ways to increase the attractiveness for Corporate Membership, as economics dictate this. One way could be to provide exhibition space free of charge at EUBS Meetings, implying that ExCom should negotiate process with SG of the Meeting and also be able to negotiate optimal exposure for the Corporate Member. Other ideas are welcomed.

8.4 The credit card machine will be cancelled, because the average cost per membership is more than 15% (as opposed to 4% for PayPal).

8.5 IBAN and BIC/SWIFT numbers of the bank account will be placed on the Website for members not wishing to use PayPal.

9. Meetings

9.1 2010 Istanbul presentation by Dr Oroglu in lieu of M Cimsit who could not make it to Aberdeen. The meeting will take place in Istanbul from 14–18 September 2010. ExCom emphasises that enough time be provided for discussions after each presentation. Suggestions are also given re the social programme, to make sure it facilitates communication between participants. ExCom is looking forward to another great meeting.

9.2 2011 Poland – a First Announcement has been distributed at the Aberdeen Meeting. There are official letters from the University of Gdansk as well as from the organizing committee; an official confirmation letter will be handed over to the Polish representatives during this meeting.

9.3 2012 Serbia – Ms Zaric and Prof T Jovanovic from the hyperbaric center Belgrade were appointed last year in Graz and will also receive an official letter of confirmation.

9.4 2013 ExCom will explore the possibility of holding a combined meeting with SPUMS, as this is in our mutual interest.

Duration of voice record: 83 min

J Schmutz
EUBS Secretary

Minutes of the Annual General Assembly of EUBS, Aberdeen, 31 August 2009

Minutes taken by P Knessl in lieu of EUBS Secretary J Schmutz, and rearranged according to agenda by P Germonpré (minutes/discussions are not necessarily in chronological order).

1. Welcome

The President Alf Brubakk (AB) welcomes all the participants with a promise of a short session as there are no controversial issues on the agenda.

2. Minutes of the General Assembly 2008 are accepted.

3. Status of current Annual Scientific Meeting.

AB thanks the meeting organisers for a well-conducted meeting, in beautiful historical buildings. Secretary General of the Meeting, John Ross, thanks his Committee for the organisation of the Annual Meeting in Aberdeen.

4. Awards and grants

4.1 The Zetterström Award for the best poster has been awarded by the Zetterström Committee (composed of P Müller, J Schmutz of the EUBS ExCom and S Watt from the Scientific Committee) to MB Havnes and co-workers from Norway for their poster "*S100 B as a biomarker for neurological DCS*". AB underlines the importance of the Award as a research stimulus and reminds the awardees that their prize, a free registration for the next meeting, is conditional on their submitting a paper from their poster to *Diving and Hyperbaric Medicine* for peer review.

4.2 Travel grants: there was only one application for a travel grant: Ben Aviner (Israel) – "*Pressure modulation of Ca2+ channels activity may elucidate HPNS mechanisms*". As both the mini-paper and presentation were of excellent quality, the author is congratulated and likewise reminded that his mini-paper should be formally submitted to our Journal for peer review, as outlined in the conditions. Y Grossman asks for clarification regarding the travel grants, notably the necessity of producing a mini-paper in order to fulfil the eligibility criteria. Reply by AB: for the moment, no changes will be made to the previously endorsed policy, simply that what the conditions are has been made clearer.

5. EUBS publications (journal and website).

5.1 AB informs the assembly about the developments re the Journal merger during the past year. The two-year trial period is running near its end, and a formal evaluation will be undertaken by the respective ExComs of EUBS and SPUMS by the end of this year. He foresees that the agreement will be solidified. P Müller (PM) informs the Assembly that an Impact Factor will be attributable to our Journal as from next year via our indexing in SCIE; PubMed indexing has been applied for and a (hopefully positive) answer should be received by the end of 2009. A

new category of articles will be published in the Journal as from the September 2009 issue: CME articles, including a quiz-like approach, based on case reports or clinical contributions. CME credits will be available to those who send back their answers to the quiz. PM asks for volunteer contributors, as the CME article in every second number should be written by European authors. AB stresses again the importance of the Journal, asks for papers.

5.2 Peter Germonpré (PG) informs about the current status of the EUBS Website. He stresses the importance and safety of online payments using the PayPal system: immediate receipt, quick renewal of membership status, secure payments. For those who experience difficulties using the PayPal system, there is the option to do a bank transfer: IBAN and BIC codes are stated on the renewal form. Of course, there is also the possibility to send cash or a cheque. The credit card option will be removed, because it is safer to use the PayPal system to pay with your credit card and secondly, this is a high financial cost for only a few members per year using it.

Planned extensions to the Website are a page listing planned or running research projects (such as the Hopon study detailed during this meeting) and another page listing upcoming courses and symposia. Of course, this needs input from all EUBS members (send to <webmaster@eubs.org>) .

The diving and hyperbaric medicine database (courtesy of GTÜEM) is accessible for EUBS members in the homepage. It now contains the full text papers of all previous EUBS Meetings, and in the near future, older numbers of the SPUMS Journal will be included.

5.3 PM remarks that due to copyright reasons, in his view, mini-papers from EUBS meetings should not be published on the site. PG proposes to make these available only to EUBS members and for a limited time. PM requests that this be reviewed in the near future.

6. Financial

6.1 The financial report was prepared by our membership secretary, Patricia Wooding (PW) and projected to the GA. Due to communication failure, it had not yet been independently audited (last year it was audited by Sarah Munday from DDRC in Plymouth). An external auditor will be sought, this can be a member of EUBS, but must not be an ExCom member. Accepted by GA.

6.2 The financial situation of our Society has recovered from a temporary 'dip' that was mainly due to increased costs related to the Journal and timing difficulties of membership renewals. It is anticipated that this will not happen in the future, as all members should pay their dues in time now. However, a Society such as ours must continuously strive to increase its membership. During the year 2008–2009, approximately 25 new members were welcomed.

6.3 Each membership year starts on 1 July of the current year, and ends on 30 June of the following year. This means that membership dues should ideally be settled from 1 May till 30 June (this corresponds with the automatic reminders sent out by the EUBS Website). Because some members apparently still pay directly in cash at the Annual Scientific Meeting, members will benefit from membership advantages (the Journal, access to the members' area of the website) until 15 September. Their membership will then be suspended until he/she renews membership.

6.4 The Financial Report is accepted by the GA.

6.5 Hans Ornhagen (HO) remarks that he would have appreciated an agenda for the GA to be published or at least handed out before the meeting; likewise, he regrets that there was no possibility to see the balance sheets beforehand. He feels the ExCom should strive better to adhere to some kind of GA meeting protocol. AB thanks him for the remarks and accepts the criticism, promises to take care of this for future meetings.

6.6 PM asks HO if he thinks the finances of the Society should be published in the Journal? HO: not necessarily, handout before the GA sufficient. Accepted by GA.

7. Votes and elections

7.1 The results of the voting ballots were as follows

Member-at-Large 2009: Andreas Möllerlökken

Vice President: Costantino Balestra

7.2 Leaving the Committee as Member-at-Large is Maide Cimsit, who is not present due to illness. The ExCom expresses their many thanks for services rendered and best wishes for her recovery.

7.3 PM remarks that we should not forget to actively seek new candidatures: each year a new Member-at-Large must be elected, and in two years we should elect a new Vice President.

8. Next meetings

8.1 Dr. Bengusu Oroglu (in lieu of Maide Cimsit) presents the programme and locations of the 36th Annual Scientific Meeting of the EUBS in Istanbul (European Cultural Capital 2010), 14–18 September 2010, followed by short film about the city and its points of interest.

8.2 Jacek Kot presents the 37th EUBS Meeting 2011 in Gdansk, Poland and the National Hyperbaric Centre in Gdynia. The meeting will be from 24–27 August 2011.

8.3 The next meeting venue has been accepted as Belgrade, Serbia, in 2012.

8.4 AB proposes that in the near future after this, a common SPUMS / EUBS meeting be organised. One of the ideas may be to hold the meeting on a 'liveaboard' or cruise ship, in order to allow participants from both hemispheres to be able to attend. Another idea would be a location somewhere half-way. AB would like to have some feedback.

8.5 Guy Williams, this year's SPUMS representative to our meeting, informs the GA participants about the upcoming SPUMS conference from 24–28 May 2010, on Redang Island, Malaysia. Information will soon be available on the SPUMS website. He encourages EUBS members to participate in the SPUMS meeting, promising a mixture of science, diving and general fun.

9. Miscellaneous

9.1 AB informs about the publication of the Proceedings of the 'Haldane Symposium', held end 2008 in Trondheim, Norway. The Proceedings have been edited and published by the Smithsonian Institute Scholarly Press. A free copy of the book can be ordered from Michael A Lang at the Smithsonian Institution or from AB.

9.2 Alf Brubakk hands the Presidency over to Peter Germonpré.

10. Closing remarks from PG

J Schmutz
EUBS Secretary

EUBS elections 2010 – call for candidates

In June 2010, elections will be organised for the EUBS Member-at-Large 2010. According to the bylaws of our Society, nominations should be prepared by the Executive Committee 100 days before the Annual Meeting. EUBS members wishing to serve the Society in this role for a period of three years should submit their application to the ExCom by e-mail <excom@eubs.org> before 31 March 2010. Applications should include a short (maximum 1 page) curriculum vitae and a representative photograph.

Elections will be by electronic ballot, so it is vital that all EUBS members make sure their e-mail addresses are correct (by logging onto the EUBS Website and verifying their personal information).

EUBS European Underwater and Baromedical Society

EUBS Annual Scientific Meeting 2010

14–18 September 2010
Istanbul (European Cultural Capital 2010)

Venue: The Marmara Hotel, Istanbul, Turkey

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Look out for full details for submission of Abstracts, Registration, Accomodation booking and Travel recommendations on the EUBS Website in the near future.

The EUBS website is at
www.eubs.org
Members are encouraged to log in

SPUMS notices and news

South Pacific Underwater Medicine Society Diploma of Diving and Hyperbaric Medicine

Requirements for candidates (updated October 2008)

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

1 The candidate must be medically qualified, and be a current financial member of the Society.
2 The candidate must supply evidence of satisfactory completion of an examined two-week full-time course in Diving and Hyperbaric Medicine at an approved facility. The list of approved facilities providing two-week courses may be found on the SPUMS website.
3 The candidate must have completed the equivalent (as determined by the Education Officer) of at least six months' full-time clinical training in an approved Hyperbaric Medicine Unit.
4 The candidate must submit a written proposal for research in a relevant area of underwater or hyperbaric medicine, in a standard format, for approval *before* commencing their research project.
5 The candidate must produce, to the satisfaction of the Academic Board, a written report on the approved research project, in the form of a scientific paper suitable for publication. Accompanying this written report should be a request to be considered for the SPUMS Diploma and supporting documentation for 1–4 above.
6 In the absence of documentation otherwise, it will be assumed that the paper is submitted for publication in *Diving and Hyperbaric Medicine*. As such, the structure of the paper needs to broadly comply with the instructions to authors – full version, published in *Diving and Hyperbaric Medicine* 2008; 38(2): 117-9.
7 The paper may be submitted to journals other than *Diving and Hyperbaric Medicine*; however, even if published in another journal, the completed paper must be submitted to the Education Officer for assessment as a diploma paper. If the paper has been accepted for publication or published in another journal, then evidence of this should be provided.
8 The diploma paper will be assessed, and changes may be requested, before it is regarded to be of the standard required for award of the Diploma. Once completed to the reviewers' satisfaction, papers not already accepted or published in other journals will be forwarded to the Editor of *Diving and Hyperbaric Medicine* for consideration. At this point the Diploma will be awarded, provided all other requirements are satisfied. Diploma projects submitted to *Diving and Hyperbaric Medicine* for consideration of publication will be subject to the Journal's own peer review process.

Additional information – prospective approval of projects is required

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

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

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

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

The Academic Board reserves the right to modify any of these requirements from time to time. As of October 2008, the SPUMS Academic Board consists of:
Associate Professor David Smart, Education Officer
Associate Professor Mike Davis
Dr Simon Mitchell.

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

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

Minutes (unconfirmed) of the Annual General Meeting of SPUMS held at Snorkelers Cove Resort, Iririki Island, Vanuatu on Thursday 28 May 2009

Opened: 1738 h

Present: The President, Dr Mike Bennett, and 28 voting members.

Apologies: Drs Scott Squires and Vanessa Haller

1. Minutes of the 2008 AGM
Minutes of the previous meeting were posted on the noticeboard.
Motion that the minutes be accepted as an accurate record.
Proposed, David Smart, seconded, Mike Bennett, carried

2. Matters arising from previous minutes
Nil

3. President's report: Dr M Bennett

4. Secretary's report: Dr S Lockley

5. Education Officer's report: Dr D Smart

6. Treasurer's report: Dr G Williams
Motion that the subscription fees are not increased for 2010. Full members AUD$150 (internet transaction); AUD$170 (manual/paper-based transaction). Associate/retired/ medical student members AUD$80 (internet transaction); AUD$100 (manual/paper-based transaction).
Proposed, Dr G Williams, seconded, Dr S Lockley, carried

7. Annual financial statements: Dr G Williams

8. Journal Editor's report: Dr M Davis

9. Election of office bearers:
The following were elected unopposed:
Treasurer: Jan Lehm
Committee members: Guy Williams
Glen Hawkins

10. Appointment of the Auditor 2009:
Treasurer Guy Williams has recommended re-appointment of Barrett, Baxter and Bye (Medical Accountants) as Auditor.
Motion that Barrett, Baxter and Bye be appointed as Auditor.
Proposed, Dr G Williams, seconded, Dr S Lockley, carried

11. Business of which notice has been given:
11.1 SPUMS diving medical outlined (President)
11.2 SPUMS Membership promotion package discussed (President)
11.3 Combined meetings EUBS/SPUMS (President EUBS, Dr A Brubakk)
11.4 Attracting new generation of young doctors to SPUMS membership (Dr A Brubakk)
11.5 Need for short diving doctor courses and concerns with availability of courses training doctors in diving medicine (Dr A McCleary).

Closed: 1828 h

President's report

In this first report from me to the membership, I want to begin by thanking the members present for continuing to support our Annual Scientific Meeting with their attendance. I am certain they will agree with me that David Smart has done a tremendous job organising this meeting – both from a social and scientific point of view. The location has proved everything he promised and the scientific programme has been excellent.

His choice of two guest speakers made for a meeting that had something for everyone interested in our field. Dr Bruce Spiess has fascinated us all with his glimpses into the world of perfluorocarbons and all they may do for us in the future. That he could make such a potentially esoteric subject accessible to us all does him great credit. Our 'local' guest, Dr Michael Taplin tackled one of the most problematic areas for diving physicians and brought the whole subject of diving and the ear into clarity. Combined with the workshop, I am sure many will leave this meeting with a great deal of confidence to deal with this complex and common set of problems. I thank both guests for their contributions and we look forward to seeing them again.

I particularly want to thank those who presented free papers. It is always a lot of work to prepare these talks and somehow more arduous when one is not required to do so for any other reason than the desire to inform and instruct one's colleagues. The ASM could not continue without these unsolicited contributions and I hope those who already contribute continue to do so. I encourage others to follow their lead.

Over the last year the focus of the Committee has been directed to three particular areas. First we have continued our formal association with the European Undersea and Baromedical Society as joint 'owners' of the Journal. This arrangement has been a nearly unqualified success. The Journal, under the ever-vigilant Mike Davis, moves from strength to strength with increasingly meritorious articles and a growing list of subscriptions. Discussions are now underway with the South African Undersea Medical

Association to form a similar alliance. Mike is now undertaking the not inconsiderable task of obtaining Medline listing to add to our EMBASE and more recently ISI (SCIE) listing. The Journal is definitely on the move.

Secondly, the Committee has been dealing with the new version of the 'SPUMS Medical'. I have presented a summary of the major changes at this meeting and we now await formal adoption of this document by the Committee at our next meeting. While the initial possibility of moving to a discretionary medical has proved unattainable, we believe the significant additions concerning asthmatic and diabetic divers are of great importance. I encourage all members who perform recreational diving medicals to become familiar with the new document.

Thirdly, we have been working on a variety of ways in which we can expand our membership. We are convinced that many doctors who dive have no knowledge of our existence and we are also concerned that the numbers of doctors prepared to perform diving medicals is contracting rather than expanding. To this end, we have developed a 'SPUMS promotional pack' that will soon be available on the website. Any member who wishes to do so is free to use this material. Consider a short presentation to your local division of general practice or hospital department! At the same time, we are concerned that the opportunities to attend short courses designed to train practitioners to a sufficient standard to perform recreational dive medicals have become severely restricted and we are encouraging the development of new courses in this area. For both of these purposes, our present website has become suboptimal. Glen Hawkins has been working hard on this and the products of his labours should be visible in the near future. Glen is also responsible for organising our next ASM and will make a presentation about his plans at the close of this ASM.

To conclude, I want to mark the retirement of one of the stalwarts of SPUMS from his position as Treasurer. Dr Guy Williams has done a fantastic job for this Society over many years as Committee Member, President and most particularly in the hard and unglamorous role of Treasurer. He will be sorely missed. I am glad to say he has agreed to have his name put forward to remain with us on the Committee and I hope we will continue to have his wise counsel and historical knowledge. Thanks for all the hard work, Guy.

SPUMS looks to the future with some trepidation in these straightened economic times, but a lot more expectation. Please stay on the road with us and consider inviting your colleagues and friends along.

Michael Bennett

Key words
Medical society, meetings

Secretary's report

My first year as Secretary has been a steep learning curve since I had been a SPUMS member for just over a year when taking on the role. Communication has been one of the major challenges in this role, particularly during times I have been deployed overseas with the Royal Australian Navy. However, the Executive Committee has met regularly through 2008–2009, and continues communication largely via e-mail in between these meetings.

Membership numbers have declined. Some of this decline is due to members changing their clinical practice or retiring from clinical medicine, others due to the merging of the EUBS and SPUMS journals, with members ceasing SPUMS membership as they now receive *Diving and Hyperbaric Medicine* through their EUBS membership. Other various reasons have been provided to us following a mail out by the President to further examine this decline. Maintaining our membership and encouraging new members continues to be a challenge to the Society and the Executive Committee will continue to explore ways of attracting new members.

SPUMS membership: current membership is 660, with full membership totalling 536, 92 associates, 27 corporate members and five life members, compared to a total membership of 725 at the same time in 2008.

I look forward to working with the new Executive Committee through 2009–10.

Sarah Lockley

Key words
Medical society, meetings

Treasurer's report

This will be my final AGM as Treasurer, as I retire as Treasurer at this meeting. SPUMS finances are very sound. Over the last three years our financial structure has been updated significantly; SPUMS currently has three bank accounts with the St George Bank, a general account for day-to-day banking, an ASM account and a journal account. These accounts are used online via Business Banking Online – all payments require two authorities, and most transactions are via EFT. SPUMS also has a business credit card account primarily to facilitate payments at our ASMs and for SPUMS Journal expenses (as an alternative to an NZ bank account). Cards are held by the Treasurer, Secretary and the Journal Editor.

An increasing number of members are using our online payments services via the SPUMS website for membership services and ASM registrations. I encourage members to use these services as this ultimately reduces costs. It is planned to significantly upgrade the SPUMS website to improve these

services. Currently our membership numbers continue to decline, as detailed in the Secretary's report.

Finally I would like to thank Steve Goble for his administrative assistance.

Guy Williams

Key words
Medical society, meetings

Special purpose financial report for the year ended 31 December 2008

The SPUMS Committee's declaration for the year ended 31 December 2008

Your committee members submit the financial report of The South Pacific Underwater Medicine Society (the Society) for the financial year ended 31 December 2008.

Committee members

The names of committee members during the last financial year and at the date of this report were:
Assoc Prof Michael Bennett, Dr Guy Williams, Dr Vanessa Haller, Dr Scott Squires, Dr Chris Acott, Assoc Prof Mike Davis, Dr Sarah Sharkey, Dr Sarah Lockley Assoc Prof David Smart, Dr Glen Hawkins

Principal activities

The aims and objectives of the Society are:

- To promote and facilitate information and research on all aspects of underwater and hyperbaric medicine;
- To provide information on underwater medicine to all interested groups. This includes diving organisations, industry, the military, as well as, the individual diver;
- To promote exchange of information between members on all aspects of underwater medicine and related subjects and to publish a quarterly journal;
- To convene members annually at a Scientific Conference.

Significant changes

No significant changes in the nature of these objectives occurred during the year.

Operating result

The net surplus of the Society for the year amounted to $22,757 (2007 $7,068).

Operating report

In our opinion:
The accompanying financial report, being a special purpose financial report, is drawn up so as to present fairly the state of affairs of the Society as at 31 December 2008 and the results of the Society for the year then ended,
The accounts of the Society have been properly drawn up and are in accordance with the books of account of the Society and
There are reasonable grounds to believe the Society will be able to pay its debts as and when they fall due.

Signed in accordance with a resolution of the Committee by Assoc Prof Michael Bennett, President, Dr Guy Williams, Treasurer
Date: 28 May 2009

Extract from the SPUMS independent auditor's report for the year ended 31 December 2008

Audit opinion

In our opinion the financial report of The South Pacific Underwater Medicine Society presents a true and fair view of the financial position of The South Pacific Underwater Medicine Society as at 31 December 2008 and the results of its operations and its cash flows for the year then ended.

Peter Bye, Certified Practising Accountant
Barrett Baxter Bye

Editor's note:
The full statement from the auditors may be obtained from the Secretary.

Education Officer's report

I have now completed a year as SPUMS Education Officer. During 2008, I have appointed an Education Board, (myself, Associate Professor Mike Davis and Dr Simon Mitchell) to review and oversee diploma projects.

SPUMS diplomas

I offer congratulations to the following doctors who have successfully completed their SPUMS diplomas since the last AGM.

May 2008
Dan Rainolds: *Blinding the blinded – assessment of the effectiveness of a sham treatment in a multiplace hyperbaric chamber trial*
Karen Richardson: *Diving expedition medicine: the Coral Cay experience*
October2008
Mark Edsell: *The use of hyperbaric oxygen therapy in the treatment of skin ulcers due to calcific uraemic arteriolopathy: experience from an Australian hyperbaric unit.*
December 2008
Graham McGeoch: *Analysis of a complex scuba diving*

The South Pacific Underwater Medicine Society Income and Expenditure Statement for the year ended 31 December 2008

	2008 $	2007 $
Income		
Subscriptions and registrations	**110,415**	110,828
Interest	**4,370**	5,055
ASM 2006 refund	**–**	8,500
EUBS	**16,521**	–
ASM 2009 profit	887	–
Sundry Income	**107**	168
Total income	**132,300**	124,551
Expenses		
Accounting fees	**1,450**	1,509
Administration, secretarial, etc	**16,798**	17,988
Amortisation of website	**–**	4,570
ASM costs	–	7,895
Office expense	**1,893**	1,338
SPUMS Equipment	**5,372**	–
Journal and editorial expenses	**66,305**	47,704
Committee expenses	**2,545**	11,264
Computer equipment	**588**	736
Maintenance website	**1,138**	8,043
Miscellaneous / subscriptions	**175**	2,006
Bank charges and card charges	**4,582**	5,548
Audit	**2,650**	2,920
Insurance	**5,200**	5,245
Telephone	**765**	382
Treasurer	**82**	335
Total expenses	**109,543**	117,483
Surplus for the year	**22,757**	7,068

The South Pacific Underwater Medicine Society Balance Sheet as at 31 December 2008

	2008 $	2007 $
Current assets		
St George General	**109,305**	39,177
St George ASM	**28,508**	23,504
St George Journal Account	**5,874**	–
ANZ Access Cheque Account	**–**	12,434
ANZ VZ Plus	**–**	44,464
ANZ SPUMS ASM	**–**	259
ASM income less expenses in advance	**–**	196
Total current assets	**143,687**	120,034
Non-current assets		
SPUMS Website – at cost	**–**	32,285
Less – provision for amortisation	**–**	32,285
Total non-current assets	**–**	–
Total assets	**143,687**	120,034
Current liabilities		
GST owing	**1,363**	467
Total current liabilities	**1,363**	467
Non-current liabilities	**–**	–
Total liabilities	**1,363**	467
Net assets	**142,324**	119,567
Accumulated funds		
Balance at beginning of the year	**119,567**	112,499
Surplus for the year	**22,757**	7,068
Balance at the end of the year	**142,324**	119,567

accident – French Pass 2000
David Cooper: *Hyperbaric chamber attendant safety: Doppler analysis of decompression stress in multiplace chamber attendants*

All projects were of a high standard and have now been published in *Diving and Hyperbaric Medicine.* Members are encouraged to submit projects for consideration for diplomas. It is our aim to facilitate SPUMS diploma projects where possible including those originating from general practice. Consideration will also be given to flexible arrangements for satisfying the service provisions of the diploma.

Diving medicine courses

Inherent in the SPUMS diploma process is a requirement that SPUMS accredits courses in diving and hyperbaric medicine and evaluates course content. There is a need to create a sound educational platform for these courses in Australia and New Zealand. Over the next 2–3 years it is intended to establish from first principles the essential content of diving medicine courses in Australia. The process of evaluating course content and how recently the course was completed, are relevant to the SPUMS diving medical and the Diving Doctors List. We intend to bring the courses in line with international standards (particularly the structures applicable in Europe), and establish a means of comparing course content. That will have three benefits:

- Australian and New Zealand courses will be able to be benchmarked against other international diving medicine courses, and perhaps create some portability/ reciprocity to the skills;
- It will enhance closer links with our European colleagues who have joined with us through the EUBS;

- It will provide some international consistency and recognition of the skill levels of doctors supporting the offshore diving industry.

It is possible after the review that there will be three levels of courses, for example:
- Basic for recreational diving medicals;
- Intermediate to cover the extra knowledge and skills to provide emergency and recompression treatment of divers, and to perform occupational medicals;
- Advanced for doctors providing support for the offshore diving industry, and provision of offshore diving medicals.

This is a huge project and will require assistance from colleagues on the SPUMS Executive and EUBS, industry stakeholders and possibly an educationalist.

David Smart

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

Editor's report

As I write this, the June 2009 issue is at its final proof-reading stage. This will be the sixth issue since *Diving and Hyperbaric Medicine* incorporated the *European Journal of Diving and Hyperbaric Medicine* as a joint venture with the European Undersea and Baromedical Society. This pooling of resources was for an initial trial period of two years, and will be reviewed by the SPUMS Executive at its face-to-face meeting at the end of the year.

During the year, the Journal achieved indexation on Science Citation Index Extended (SCIE). This is an important step in enhancing the international reputation of the Journal as it will now provide an Impact Factor for the Journal as time progresses. Also, in some ways, this is at least as important as indexation on Index Medicus as SCIE has a much broader coverage across the scientific disciplines, thus enhancing access to DHM papers for literature searches.

Recently a preliminary expression of interest, the first step in the process, was sent to the National Library of Medicine in the USA requesting inclusion within Index Medicus. We have yet to hear whether the Journal has passed this initial hurdle so that we can move forward to listing.

The number of manuscripts submitted to the Journal in 2008 doubled compared to any previous year, and this has been maintained thus far in 2009. Peer review has been enhanced, with at least two reviewers, one from the Editorial Board (formed at the beginning of 2008) and one external, providing input for all original articles, case reports and reviews and for some of the other items in the Journal. When I commenced as Editor in 2002, I opted for open review, that is, both the authors and the reviewers know who each other are, as a fairer process. This has proved a positive move, and has resulted in some cases in a reviewer working with the authors to enhance their work.

The Editorial Board of six members, three from each Society, plus the Editor, has been working well, but we still have some way to go in fully developing Journal policy and the structures needed for us to work together as a close-knit group. The problem for all of us is the all too familiar one of lack of time, and being spread too thinly across our varied professional responsibilities. I would like to thank my colleagues on the Board for their excellent support during our first year. I would like to propose for 2010 onwards that we invite two more members onto the Board to spread the increased workload. If anyone is interested in contributing, please contact the President or myself. In conclusion, the writer believes that the first year of a combined journal with EUBS has been a resounding success in every respect and that there is every expectation this will continue.

Mike Davis

Key words
Writing – medical, meetings, medical society

Annual General Meeting of the Australian and New Zealand Hyperbaric Medicine Group 2009
13 August, 2009, Fremantle, Western Australia

Opened: 1645 h

1. Attendance
D Smart, D Wilkinson, M Bennett, S Szekely, H Oxer, F Sharp, C Meehan, B Bloch, B Webb, N Banham, G Hawkins
The Chair welcomed Dr John Feldmeier, (USA) and Mr David Oliver.

2. Apologies
B Trytko, M Walker, M Hodgson, D Cooper, M Davis, I Millar, K Thistlewaite

3. Minutes of 2008 Annual General Meeting
Accepted as an accurate record (moved Hawkins, seconded Bennett)

4. Business arising
Incorporated into current agenda

5. Address by Chair of ANZHMG (D Smart)
5.1 Hyperbaric medicine funding in Australia – MSAC
The main issue on the agenda for the ANZHMG over the last 12 months has been the Federal Government Medical

Services Advisory Committee. We are again required to submit full applications to maintain the Medicare funding for hyperbaric oxygen treatment of soft-tissue radiation injury and necrosis and also for non-diabetic problem wounds where hypoxia can be demonstrated. Even though the funding for these two conditions is due to expire on 01 November 2010, MSAC required that we resubmit 18 months in advance, to provide them with enough time to evaluate the submissions prior to the deadline for funding.

The MSAC process has grown significantly since it started. We now need to submit three different sections, all linked together via their 40+ page submission form (which also needs to be filled out in its entirety). The three major sections are:

A full description of the epidemiology, disease load, and safety of treatment using the proposed therapy;
A full Cochrane standard literature review, classifying and critiquing the evidence for the therapy (and in our case, the alternative therapies);
A full review of the cost effectiveness of the treatment including quality of life advantages.

To gain a perspective of the task, the Federal Government usually contracts reviewers from the Monash Centre for Clinical Effectiveness to perform MSAC reviews, at a cost of around $250,000. Clearly this is a huge project and it is nearing completion.

Despite significant efforts by ANZHMG members, we were unable to complete the submissions by May 2009. Via my contact at the Australian Healthcare and Hospitals Association (CEO, Prue Power), I was able to hook up a teleconference, with the Medical Administrative Executive Officer of MSAC, Dr Brian Richards. At that teleconference, I presented information about the challenges facing us with the submissions (e.g., the difficulties of recruiting sufficient numbers to the HORTIS trials), as well as the major issue as we saw it, that MSAC had been examining HBOT in isolation, when they should have been examining evidence from a patient's perspective. Dr Richards was very receptive to this strategy.

My teleconference with Dr Richards back at the start of May 2009 was very productive. He indicated that our proposal was similar to the perspectives of government strategic direction for MSAC. They were keen to review the whole CMBS schedule using evidence-based principles, and that to do this review from a patient's perspective was where they wanted to be (I will be very surprised if they ever achieve this goal as MSAC has been extremely slow in dealing with even basic submissions from one speciality such as ours). Irrespective of this, we are uniquely placed to lead the strategic direction by submitting our next documents viewing the evidence from a patient perspective. For the last six months, I have been reviewing all of the evidence for all treatments of soft-tissue radiation injury, and hyperbaric oxygen treatment has evidence that is equal to or better than alternatives for this condition. Glen Hawkins is working on a similar submission regarding hypoxic non-diabetic wounds and the evidence for all therapies available. We plan to meet again with Dr Brian Richards in late September to negotiate the next phase of submission.

5.2 SPUMS issues

This is a separate agenda item.

5.3 Research

HOLLT: Congratulations to Ian Millar for his work with the HOLLT trial. Unfortunately his facility is currently not operational. RHH now has $250,000 of funding to enrol patients for the trial, from Tasmania's Motor Accident Insurance Board. I would encourage other centres in Australia to participate.

HORTIS: Recruitment is very slow for other arms of the HORTIS trial. Given the prominence of this group of trials and its potential link to funding, I am concerned about this and again I would encourage facilities in Australia in the trial.

5.4 ANZHMG list of indications for hyperbaric oxygen treatment.

This is due for review again this year, having last been published in *Diving and Hyperbaric Medicine* 2007.

5.5 Review of Health Technology Assessments

On another front, the Federal Government in April called for expressions of interest to their review of Health Technology Assessments (i.e., an opportunity to say our piece about MSAC to the reviewers). I wrote in April to register our interest and then I attended a meeting in Melbourne in early June 2009. At this point, I submitted our concerns about the MSAC process. ANZHMG is now registered with this review and after the draft report is put together ANZHMG will have further opportunity for comment.

5.6 Support for the HTNA conference

I encourage all ANZHMG members to provide contributions to the conference. It is a unique event that needs to be supported and I congratulate the Fremantle team in running this year's conference.

5.7 Courses in diving and hyperbaric medicine

The Royal Adelaide Hyperbaric Medicine Course continues under the supervision of Dr Chris Acott. The remaining courses in Australia are the Prince of Wales Introductory Course in Diving and Hyperbaric Medicine and also the Royal Australian Navy Course at HMAS Penguin. There are plans by SPUMS to undertake a review of the educational requirements for these courses and also to align them with overseas courses (especially Europe). This will probably take around 2–3 years, led by the SPUMS Education Officer.

5.8 Royal Hobart Hospital Department of Diving and Hyperbaric Medicine review 2008

I thank all members for their support when the future of the RHH facility was under threat. The review of our service has been cancelled, and our future is assured, although there will be no new hospital in Hobart in the

foreseeable future.

6. MSAC and Federal Government funding issues
Covered in Chairman's address.

7. Hyperbaric problem wound study
Dr Hawkins reported that the database is continuing to build, with about 400 patient records. A paper to be submitted for journal publication is almost complete detailing the first three years of data. Hyperbaric facilities not contributing data were identified: Alfred Hospital, Royal Darwin Hospital, Fremantle Hospital. All units were encouraged to join this prospective data collection. While the number of patients is important, the perception that all hyperbaric facilities in Australia and New Zealand are involved sends an invaluable message. Current data will be presented as a talk during the meeting.

8. HORTIS
Covered in Chairman's address.

9. ANZHMG/SIG list of approved indications for hyperbaric oxygen therapy
This is a list of indications for HBO treatment that we feel can be justified on the basis of a review of the evidence from the current literature. It is intended to be a dynamic list with inclusions and deletions as seen fit. The process expects that any suggested change should be debated at an appropriate venue with speakers nominated to present pro and con positions using an evidence-based approach. A consensus decision will then be sought. Against each indication on this list there are a number of hyperbaric treatments specified. This number is intended to suggest that review of the patient's condition should be undertaken at this point with more hyperbaric treatment ordered if it is felt appropriate. It is not intended to be considered a maximum treatment allocation for that indication. It is apparent that this has been the source of some confusion and practitioners are reminded of the intent of this part of the list.
(Action: Dr Wilkinson to e-mail a copy of the current list over the chatline)

10.Introductory Course in Hyperbaric Medicine
The ANZHMG-sponsored course currently run at the Prince of Wales Hospital continues to attract good attendance and receives positive feedback from participants. The course will be held at Prince of Wales next year, but in a different location due to major rebuilding of the Department of Diving and Hyperbaric Medicine. The dates are 22 February to 5 March 2010. The courses run at the Royal Adelaide Hospital and at HMAS Penguin were mentioned.

Broader discussion evolved regarding a mechanism to review the current courses. SPUMS appears to have been cast as a *de facto* judge of course suitability with several documents, Australian Standards included, referring people to SPUMS for an appropriate course to develop skills in this area. The idea is that SPUMS, probably via the Education Officer, should review the current courses. The content for courses should be aligned with international standards for dive medicals, this may be particularly useful in the recreational diving field. Recognition of training to perform dive medicals in the occupational field, particularly in our region of the world, continues to be somewhat uncertain since the HSE stopped approving doctors outside of the UK.

11. Hyperbaric facility accreditation
While the rest of the Hospital seeks accreditation through the process controlled by ACHS, the very specific and unique characteristics of hyperbaric facilities probably fall outside the scope and/or ability of the ACHS. However, the ANZHMG does not currently see a role for it to become involved with facility accreditation in a way similar to the UHMS in the USA. It is noted the Australian Standard 4774.1 covers many operational issues. This item will be removed from the agenda of future meetings. (The process of accreditation for training in hyperbaric facilities is overseen by the SIG in Diving and Hyperbaric Medicine of the ANZCA and is not to be confused with the facility accreditation discussed.)

12. Australian Standards
There has been no particular activity relevant to our group in the past 12 months. It is noted that Standards Australia is now a private company – SAI. This has led to significant change in how it operates. For example, if a particular group wished to revise an existing Standard it would be the responsibility of that group to fund the whole process. The move towards international consistency with ISO standards superseding Australian Standards was discussed particularly in regard to the impact it may have on existing standards for diving in Australia.

13. *Diving and Hyperbaric Medicine*
The Editor gave an apology for this meeting. However, the dramatic improvement in the standard of original research was noted. Since the amalgamation with EUBS there has been a significant increase in submitted articles and journal planning is now several issues in advance. It was reported that there have been positive responses to the possibility of the South African Society joining this journal, along with ICHM. Discussions are continuing.

14. Minimum data set / registry developments
Dr Webb reported that having looked at the variety of databases used by facilities, and the range of data collected, he has been developing a common dataset using easily accessible software (Access).
(Action: Dr Webb to circulate the progress of this dataset via chatline)

15. Hyperbaric medicine clinical indicators
The collection of these clinical indicators has commenced

throughout the units this year. It will be discussed as a scheduled talk during this meeting. People were reminded that we expect these clinical indicators will be redefined and perhaps added to over time.

16. Clinical trials for discussion

It was noted that we should aim to set aside dedicated time at this meeting to discuss clinical trials, how to progress these and seek multicentre associates where appropriate. Progress of both the HOLLT and HORTIS studies was discussed and applauded. Dr Bennett commented that the unit at the Prince of Wales holds a research meeting weekly and access to some of this information may be relevant to other units.

(Action: Dr Bennett to notify availability of local meeting information via email)

(Action: Dr Smart to negotiate dedicated time slot for subsequent HTNA meetings)

17. HTNA issues

Several people commented that they were not aware of advertising for the HTNA meeting until late. Some noted that while this was published in the *Off-Gassing* journal, they have not received a copy of *Off-Gassing* for some time. It was thought that perhaps their annual associate membership had lapsed; however, they had not been notified of any requested renewal. Perhaps limited awareness had something to do with a significant number of meeting registrations having been received in the last couple of days (some 25 people?).

(Action: Dr Smart to discuss with the HTNA regarding the process for notifying membership renewal and earlier/broader meeting advertising generally)

18. Other business

18.1 SPUMS ASM

Dates for the 2010 ASM have been finalised and will be published in the Journal. The meeting will be held in conjunction with the Asian Hyperbaric and Diving Medicine Association. The venue will be Redang Island on the east coast of Malaysia. Travel arrangements have been streamlined to allow internet bookings. The structure of the meeting will be different to allow booking for the number of dives desired rather than a fixed number. The visitor has been confirmed as Dr Mike Gernhardt – diver, NASA astronaut and scientist.

18.2 SPUMS website

This is being updated, particularly to improve the Diving Doctors list.

18.3 Australian Hyperbaric and Diving Medicine Research Trust

Round two of the grant scheme has been announced for 2010. $30,000 is available for successful applications. See <www.hyperbaricresearch.com.au>.

Meeting closed: 1800 h

David Wilkinson, Hon Secretary, ANZHMG

ANZHMG Accepted Indications for Hyperbaric Oxygen Therapy

The indications as published in *Diving and Hyperbaric Medicine*. 2007;37(1):35 have been reviewed and approved for a further two years without change by the ANZHMG sub-committee of SPUMS as of September 2009.

Please see the above citation or view the list on the ANZHMG page (under construction) of the SPUMS website <www.spums.org.au>.

Education Officer's report, October 2009

SPUMS diplomas

No new diplomas have been awarded since the May ASM. Two new projects have been registered and approved.

Dr Katherine Commons: A prospective analysis of independent patient risk factors for middle ear barotrauma in a multiplace hyperbaric chamber

Dr Marianne Sidhom: An analysis of the incidence and risk factors for pain in chronic wounds, and the effect of hyperbaric oxygen treatment

Diving medicine courses and recognition of prior learning

Progress on this has been slow, due to other heavy commitments. As mentioned in the 2008 report, the assessment of diving medicine courses is a huge project that will require assistance from colleagues in both SPUMS and EUBS, diving industry stakeholders and others. I have scheduled 2010 and beyond for this project. In the interim, I am assessing individual requests for recognition of prior learning on a case-by-case basis.

Associate Professor David Smart

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

The SPUMS website

By the time you receive this issue of the Journal, the new website will be up and running.

There are several reasons why we had to change the website and other reasons why we wanted to make changes. The main reason is to make the website more user friendly. The old website was becoming unwieldy and changing the information on the site was becoming more and more tedious, hence the lack of major changes in recent times. There are also new features that we have added, such as a forum and map and criteria search for the diving doctors list. The latest versions of the Journal *Diving and Hyperbaric Medicine* will be available online to all financial members of SPUMS and EUBS, and versions older than two years will be available in the public domain on the Rubicon Foundation website <www.rubicon-foundation.org>.

The other reason for upgrading the website is to do with security. The website was originally based on an old form of software that now has some serious security issues for the site (on-line transactions were not affected, just that people could change what was on the site) and the upgrade to this was going to be very expensive. We now use an 'open-source' version of the Drupal Content Management System (CMS) which is kept up to date on a much more regular schedule. We have also done some work on updating member profiles and removing some legacy data that were no longer relevant.

Improving the user interface will be ongoing, making it easier to navigate around the site. The search mode of the old site often did not find things that people were looking for, but this should be a thing of the past, so hopefully the new site will be much more user-friendly and become a more active website for everyone to use. We also hope to keep people more up to date via the website and e-mail, so when you visit the site please look at your own profile and make sure that your information is correct and up-to-date.

Most importantly, please provide an e-mail address in your personal data. We only have e-mail addresses for about a third of the membership.

I look forward to seeing you on the forums!

Glen Hawkins, SPUMS Webmaster

Australian and New Zealand College of Anaesthetists

Certificate in Diving and Hyperbaric Medicine

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

Eligibility criteria are:

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

2 Completion of training courses in Diving Medicine and in Hyperbaric Medicine of at least 4 weeks' total duration. For example, one of:
   - a ANZHMG course at Prince of Wales Hospital Sydney, **and** Royal Adelaide Hospital or HMAS Penguin diving medical officers course **OR**
   - b Auckland University Diploma in Diving and Hyperbaric Medicine.

3 **EITHER:**
   - a Completion of the Diploma of the South Pacific Underwater Medicine Society, including 6 months' full-time equivalent experience in a hyperbaric unit and successful completion of a thesis or research project approved by the Assessor, SPUMS
   - b **and** Completion of a further 12 months' full-time equivalent clinical experience in a hospital-based hyperbaric unit which is approved for training in Diving and Hyperbaric Medicine by the ANZCA.

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

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

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

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

Dr Margaret Walker, FANZCA, Cert DHM (ANZCA)
Chair, ANZCA/ASA Special Interest Group in Diving and Hyperbaric Medicine

1st Joint Meeting
South Pacific Underwater Medicine Society
Asian Hyperbaric and Diving Medical Association

The 39th SPUMS Annual Scientific Meeting combined with the 6th ASM of the Asian Hyperbaric and Diving Medical Association

23–28 May 2010

Venue: Redang Island Beach Resort

Theme: Decompression and Hyperbaric Medicine into the 21st Century

SPUMS Guest Speaker
Michael L Gernhardt, PhD
NASA Astronaut, Manager of the Environmental Physiology Laboratory and
Principal Investigator of the Prebreath Reduction Program
Johnson Space Center, Houston, Texas

AHDMA Guest Speaker
Folke Linde, MD, PhD
Professor, Department of Anaesthesiology, Surgical Services and Intensive Care
Karolinska University Hospital, Stockholm, Sweden

MEETING CONVENOR
Dr Glen Hawkins
PO Box 1674
Maroubra, NSW 2035
AUSTRALIA
E-mail: <glen@hawkeyemedical.com.au>

Full details for submission of Abstracts and Posters,
Registration, Accomodation details and Travel recommendations
can be found on the SPUMS website.
Members are urged to book early.

The
website is at
www.spums.org.au

Introducing Nicky McNeish

Editorial Assistant, Diving and Hyperbaric Medicine

I am a mother of three children, living in Tai Tapu, near Christchurch, New Zealand. Prior to having my family, I was the senior reception manager/secretary at a large construction company. I recently graduated with a *Diploma of Knowledge and Emerging Technologies* from the Open Polytechnic of New Zealand. This included web design and writing for the web, web programming, collaborative technologies, E-commerce and future trends, not all of which are relevant to this Journal! I take an active role in my children's school as President of the PTA. I have many passions in my life; these include running, water colour painting on canvas, viticulture, reading, gardening and coffee, for which I am a trained barista. Working for a medical journal is very much a new project for me.

SPUMS Hyperbaric Technical and Nursing Association Award

The SPUMS Award for the best paper by an HTNA member at the HTNA ASM in Freemantle 2009 was awarded to Gordon Bingham (The Alfred, Melbourne) for his paper entitled "*Patterns of oxygenation in mechanically ventilated intensive care patients following hyperbaric oxygen treatment*." Mr Bingham was also a recipient of a Hyperbaric Health/DAN Asia-Pacific grant to conduct this research.

Obituary

John Betts

Dr John Betts, who advised the British Sub-Aqua Club (BSAC) on medical matters for many years, has died aged 83. John joined the BSAC London branch in 1959, and by 1966 was on the BSAC Council. Two years later, he became Medical Officer and Chairman of the BSAC Medical Committee. He was instrumental in introducing regular diving medicals for members and was involved in overseeing the courses for prospective diving doctors run at the Institute of Naval Medicine, Alverstoke. He carried out pioneering research in the 1960s on the thermal properties of neoprene wetsuits, demonstrating the changes in thickness and loss of insulation with depth. Retiring as Chairman of the Medical Committee in 1981, John remained closely connected with diving medical developments and policies within the BSAC as Honorary Vice-President, and continued to attend council meetings until his final illness took hold.

In 1993, he received the Robert Atkins Award from the Institute of Sports Medicine for his "*consistently valuable medical service to a national organisation*". He was also aware of the value of the media in promoting efficient, safe diving practices, and had a long association as medical consultant to *Triton* and its successor, *Diver*, the leading diving magazine in the United Kingdom.

Other interests included underwater photography, an enthusiastic approach to computers and, unrelated to diving, was keen on genealogy. "*My memory of him is of a quiet, competent, kindly man, and a true friend*," said George Brookes, BSAC Chairman, 1958–61 and Honorary Life Member. "*He was utterly loyal to the club, discreet and [he] respected confidentiality*." He carries the affection of all who knew him and the respect of those who have benefited from his sage advice and medical work for all divers, BSAC or otherwise. Dr Betts is survived by his wife, two sons, a daughter and grandchildren.

ABC purchases Best Publishing Company

American Baromedical Corporation recently purchased Best Publishing Company. Best Publishing was founded in 1966 by Jim and Susan Joiner, specialising in the publication of professional and educational books on diving, hyperbaric medicine, and wound care. The company will remain under the direction of the Joiners.

British Hyperbaric Association 2010 Annual Conference

19 – 21 November

James Paget University Hospitals NHS
Lowestoft Road
Gorleston Great Yarmouth
Norfolk NR31 6LA

For further information contact:
Karen Turner <karen.turner@jpaget.nhs.uk>
Or
Maxine Palmer <maxine.palmer@jpaget.nhs.uk>
Phone: +44-(0)1493-453526
Fax: +44-(0)1493-453261

Scott Haldane Foundation, The Netherlands

The Scott Haldane Foundation is dedicated to education in diving medicine, and has organised more than 100 courses over the past few years, both in the Netherlands and abroad. Below is an overview of courses planned for 2010.

More information can be found at:
Website: <www.scotthaldane.nl>
E-mail: <info@scotthaldane.nl>

16 January: Refresher course "Neurology and diving" (AMC, Amsterdam, NL)
1–8 February 2010: 16th Advanced course "Diving and ENT" (Kri, Raja Ampat, West-Papua)
09–17 April: Basic course in diving medicine (AMC, Amsterdam, NL)
June: 16th Advanced course "Diving and ENT" (Driebergen, NL)
June: Advanced course "Evidence-based diving medicine" (Driebergen, NL)
October: Refresher course "Neurology and diving" (NL)
6–13 November: Basic Course diving medicine (Zanzibar, Tanzania)
13–20 November: 17th Advanced course in diving medicine (Zanzibar, Tanzania)
20–27 November: 17th Advanced course in diving medicine (Mafia Island, Tanzania)

17th International Congress of Hyperbaric Medicine (ICHM) 2011

Dates: 16–19 March 2011
Venue: Cape Town International Convention Centre, Cape Town, South Africa

Information can be found on the South African Underwater and Hyperbaric Medicine Association (SAUHMA) website:
<http://www.sauhma.co.za >

Hyperbaric Medicine 2010

22–24 April 2010
Columbia, South Carolina

National Baromedical Services, Inc, in association with Palmetto Health, is proud to announce the 13th Advanced Hyperbaric Symposium.

For more information please visit:
<http://www.baromedical.com/HBO2010>
Register now to take advantage of Early Bird Specials

Undersea and Hyperbaric Medical Society Annual Scientific Meeting 2010

Dates: 3–5 June 2010
Venue: Tradewinds Grand Island Resort
St Pete Beach, Florida, USA

Pre-courses: 2 June
Wound care
How to prepare for accreditation

UHMS is accredited to provide continuing medical education for physicians

Full details of the programme, registration and accomodation are available on the UHMS website <www.uhms.org> or
for further information contact:
Lisa Tidd, UHMS
Phone: +1-(0)877-533-UHMS/919-490-5140
E-mail: <lisa@uhms.org>

German Society for Diving and Hyperbaric Medicine (GTUEM)

An overview of basic and refresher courses in diving and hyperbaric medicine, organised by the GTUEM in Germany, can be found at:
<http://www.gtuem.org/212/Kurse_/_Termine/Kurse.html>

Finnish Society for Undersea and Hyperbaric Medicine

Advanced Diving Accident Life Support (ADALS),
5–12 March 2010
Phi Phi Island, Thailand

Extension (diving) possible till 20 March
This 5th edition of the ADALS is aimed at medical doctors, but diving instructors have participated in the past … and survived!

Contact Timo Jama, President of UHMSFin at:
<timo.jama@hus.fi>

The Australia and New Zealand Hyperbaric Medicine Group

Introductory Course in Diving and Hyperbaric Medicine

Dates: 22 February to 5 March 2010
Venue: Prince of Wales Hospital, Sydney, Australia

Course content includes:
- History of hyperbaric oxygen
- Physics and physiology of compression
- Accepted indications of hyperbaric oxygen (including necrotising infections, acute CO poisoning, osteoradionecrosis and problem wound healing)
- Wound assessment including transcutaneous oximetry
- Visit to HMAS Penguin
- Marine envenomation
- Practical sessions including assessment of fitness to dive

Contact for information:
Ms Gabrielle Janik, Course Administrator
Phone: +61-(0)2-9382-3880
Fax: +61-(0)2-9382-3882
E-mail: <Gabrielle.Janik@sesiahs.health.nsw.gov.au>

This course is approved as a CPD Learning Project by ANZCA – Cat 2, Level 2 – 2 credits per hour (Approval No. 1191).

Royal Adelaide Hospital Diving Medicine Medical Officers and Diver Medical Technician Courses 2010

Medical Officers Course:
Week 1, 21–25 June
Week 2, 28 June – 2 July

Full DMT Courses:
22–26 February
2nd DMT course in November still t.b.d.

DMT Refresher Course:
26–30 October

For more information contact:
Lorna Mirabelli
Senior Administrative Assistant
Hyperbaric Medicine Unit, Royal Adelaide Hospital
Phone: +61-(0)8-8222-5116
Fax: +61-(0)8-8232-4207
E-mail: <Lmirabel@mail.rah.sa.gov.au>

Interuniversity Diploma in Diving and Hyperbaric Medicine, France

University Course (1-year duration) in diving and hyperbaric medicine, organised concurrently by 13 French universities (Angers, Antilles-Guyane, Besançon, Bordeaux II, Lille 2, Lyon II, La Réunion, Marseille, Nancy, Nice, Paris XIII, Strasbourg, Toulouse).

Information on <http://www.medsubhyp.org> and <http://medecine.univ-lille2.fr/format/diu/hyperbar.htm>

Conference proceedings available The future of diving: 100 years of Haldane and beyond

Michael A Lang and Alf O Brubakk, editors

Smithsonian Institution Scholarly Press

The proceedings of "*The Future of Diving: 100 Years of Haldane and Beyond*" symposium, convened 18–19 December 2008 in Trondheim, Norway, by the Baromedical and Environmental Physiology Group of the Norwegian University of Science and Technology, are reported in 28 papers and 3 discussion sessions.

Download a PDF of this publication through:
<www.scholarlypress.si.edu>

To request a print copy, e-mail SISP at:
<schol_press@si.edu>
Print copies of this publication are free upon request, while supplies last; limit five (5) copies.

The Hyperbaric Research Prize

The Hyperbaric Research Prize encourages the scientific advancement of hyperbaric medicine and is awarded annually whenever a suitable nominee is identified. It will recognise a scholarly published work or body of work(s) either as original research or as a significant advancement in the understanding of earlier published science. The scope of this work includes doctoral and post-doctoral dissertations. The Hyperbaric Research Prize is international in scope. However, the research must be available in English. The Hyperbaric Research Prize takes the form of commissioned art piece and US$10,000 honorarium.

For detailed information please contact:
Baromedical Research Foundation
5 Medical Park, Columbia, SC 29203, USA
Phone: +1-803-434-7101
Fax: +1-803-434-4354
E-mail: <samir.desai@palmettohealth.org>

Instructions to authors

(revised March 2009)

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:
The Editor, Diving and Hyperbaric Medicine,
C/o Hyperbaric Medicine Unit, Christchurch Hospital,
Private Bag 4710, Christchurch, New Zealand.
E-mail: <spumsj@cdhb.govt.nz>

Requirements for manuscripts
Documents should be submitted electronically on disk or as attachments to e-mail. The preferred format is Microsoft® Office Word 2003. 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 generally be subdivided into the following sections: an Abstract of no more than 250 words, Introduction, Methods, Results, Discussion, Conclusion(s), Acknowledgements and References. Acknowledgements should be brief. Legends for tables and figures should appear at the end of the text file after the references.

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. 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.

The preferred length for original articles is up to 3,000 words. Including more than five authors requires justification, as does more than 30 references. Case reports should not exceed 1,500 words, with a maximum of 15 references. Abstracts are required for all articles. Letters to the Editor should not exceed 500 words with a maximum of five references. Legends for figures and tables should generally be less than 40 words in length.

Illustrations, figures and tables must 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.
Table data may be presented either as normal text with tab-separated columns (preferred) or in table format. No gridlines, borders or shading should be used.
Illustrations and figures should be submitted as separate electronic files in TIFF, high resolution JPG or BMP format. If figures are created in Excel, submit the complete Excel file. Large files (> 10 Mb) should be submitted on disk.
Photographs should be glossy, black-and-white or colour. Colour is available only when it is essential and may be at the authors' expense. Indicate magnification for photomicrographs.

References
The Journal reference style is the 'Vancouver' style (Uniform requirements for manuscripts submitted to biomedical journals, updated May 2007. Website for details: <http://www.nlm.nih.gov/bsd/uniform_requirements.html>). References must appear in the text as superscript numbers at the end of the sentence 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/tsd/serials/lji.html>). Examples of the exact format for a standard paper and a book are given below:

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

Place a full stop after the journal name and at the end of the reference. Titles of books and journals should be in italics. Accuracy of the references is the responsibility of authors.

Any manuscript not complying with the above requirements will be returned to the author before being considered for publication.

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.

Copyright
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Full instructions to authors (revised June 2009) can be found on the EUBS and SPUMS websites.

DIVER EMERGENCY SERVICES PHONE NUMBERS

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

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

SOUTH-EAST ASIA
+852-3611-7326 (China)
010-4500-9113 (Korea)
+81-3-3812-4999 (Japan)

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

EUROPE
+39-06-4211-8685 (24-hour hotline)

UNITED KINGDOM
+44-07740-251-635

USA
+1-919-684-8111
+52-5-629-9800 (America-Mexico))

LATIN AMERICA
+1-919-684-9111 (may be called collect; Spanish and Portuguese)

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

DAN Asia-Pacific DIVE ACCIDENT REPORTING PROJECT

This project is an ongoing investigation seeking to document all types and severities of diving-related accidents. Information, all of which is treated as being confidential in regard to identifying details, is utilised in reports on fatal and non-fatal cases.

Such reports can be used by interested people or organisations to increase diving safety through better awareness of critical factors.

Information may be sent (in confidence unless otherwise agreed) to:

DAN Research
Divers Alert Network Asia Pacific
PO Box 384, Ashburton VIC 3147, Australia
Enquiries to: <research@danasiapacific.org>

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-AP website: <www.danasiapacific.org>
They should be returned to:
DIMS, 30 Park Ave, Rosslyn Park, South Australia 5072, Australia.

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