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Diving expeditions:
from Antarctica to the Tropics

Diving deaths in New Zealand

Epilepsy and diving – time for a change?

Mechanical ventilation of patients at pressure

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PURPOSES OF THE SOCIETY

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

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MEMBERSHIP

Membership is open to all medical practitioners.
Associate membership is open to all those who are not medical practitioners but are interested in the aims of the Society, and/or those engaged in research in underwater medicine and related subjects.
Membership is also available for retired medical practitioners and medical students.

Membership applications are best completed online at the Society's website <www.SPUMS.org.au>

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

To travel to and dive in exotic and remote parts of the world appeals to many of us. Certainly, as a medical society, SPUMS has done its fair share, all in the name of continuing medical education. Providing collegiate opportunities for diving physicians to not only meet in scientific session but to dive together in the environment they are supposed to know something about has been a legitimate undertaking for the majority of those attending such meetings. However, most delegates probably do not give much thought to the logistical, safety and medical challenges of such short trips, orchestrated for us as they are by travel professionals.

The planning for long-term (that is, over many years) remote expeditions is of an entirely different nature to catering for our tourist party for a week or two each year. In this issue, the needs of diving research in two of the geographical and meteorological extreme environments on Earth are presented in articles by Neal Pollock (Antarctica) and Karen Richardson (the Tropics). Neal talks from hands-on experience of several seasons down on 'The Ice', testing diving equipment and undertaking physiological research, whilst Karen analyses from a medical perspective the large database accumulated by a remarkably successful marine science amalgamation of professional scientists and lay volunteers, the Coral Cay Conservation (CCC) Project.

Both reports illustrate how thorough advance planning, selection of personnel and the right equipment and materials result in good safety records in such environments far from the madding crowd. Sadly since the CCC data were analysed, a death has occurred at one of the Fiji sites, where an expedition member was apparently electrocuted by a falling power cable during a tropical storm. Some contingencies cannot be planned for, however hard one tries. That the published medical data from expeditions are so limited is somewhat surprising, given the many contemporaneous journals published by explorers and field scientists. CCC are to be congratulated not only on their focus on near-real time reports, but also for encouraging analysis and publication of these data.

Every diving fatality is one too many. The stories summarised over the years in Douglas Walker's Project Stickybeak and now in Andrew McClelland's report from New Zealand make incredibly sad reading. For me, the most poignant in this paper is the lady, diving overweighted, who sank to the bottom in only 7 msw depth immediately beneath the boat, losing her fins in the process and rapidly drowning despite having a full tank of air and having never released her weight belt. Could there be a more striking example of how panic underwater destroys rational thinking?

Yet again, familiar features crop up time after time: inexperience, panic, solo diving, buddy separation, failure to release the weight belt, buoyancy problems, out-of-air situations, wearing a weight belt but no fins or floatation device when snorkelling and lack of medical and/or physical fitness.

With regard to medical fitness, at a time when the sport diving population is ageing, it seems absurd that the new international standard likely to be brought in (watch this space!) will ease the medical requirements for recreational scuba training. There is also a major dichotomy here between the recreational diving industry, which wishes diving physicians to provide absolutes about diving 'fitness' and the discretionary and risk-management approach increasingly favoured by diving physicians and the law, as enshrined in disability legislation.

This brings me to the review article from *Epilepsia* discussing whether people with epilepsy, past or present, should be allowed to dive. We are indebted to the publishers, Wiley-Blackwell, for allowing us to reprint this, as it is an important review article. A background commentary on moves in this area in the United Kingdom is provided following the article. I hope that these topics will generate vigorous, informed debate in the 'Letters' column.

Those readers who bother to read the 'News and notices' section each issue will be aware that for some two years now, the SPUMS Committee and the European Underwater Baromedical Society (EUBS) have been discussing the potential benefits and pitfalls of incorporating the *European Journal of Underwater and Hyperbaric Medicine* (EJUHM) into *Diving and Hyperbaric Medicine* (DHM) as a single international journal. EJUHM was first published in 2000, but has struggled since its inception to really establish itself, despite the enthusiastic efforts of its Editor, Dr Peter Mueller, whereas the *SPUMS Journal*, now DHM, has continued to develop slowly but surely over the years. Both SPUMS and EUBS see this as a real opportunity to establish closer ties within the international diving and hyperbaric medical community, whilst retaining the strong emphasis on diving medicine that has always been a feature of SPUMS and its journal.

As of the March issue next year, DHM will become the joint voice of both societies. More details on these developments will be provided in the next issue. For current readers, the likely impact is a better journal, with a continued commitment to providing a varied, interesting range of topics within its pages for what is a very diverse membership.

Michael Davis

Cover photo taken by Martin Sayer of a black coral, *Antipathes fiordensis*, with an entwined perching snakestar, *Astrobrachion constrictum*, found only on black coral in a symbiotic relationship (Fiordland, New Zealand, 2007). Dr Sayer also took all but two of the photos in the montage on page 198.

Original articles

Diving-related deaths in New Zealand 2000–2006

Andrew McClelland

Key words
Diving deaths, deaths, drowning, scuba diving, breath-hold diving, diving accidents, case reports

Abstract

(McClelland A. Diving-related deaths in New Zealand 2000–2006. *Diving and Hyperbaric Medicine*. 2007; 37: 174-88.)
A review of the epidemiology of diving-related deaths over the seven years from 2000 to 2006 in New Zealand was undertaken. The circumstances of each case, the method of accident investigation and the coroner's reports were reviewed, assessing the detail, accuracy and appropriateness of each. Descriptive summaries are provided for the deaths related to scuba diving. In total, 56 diving-related fatalities, 40 scuba divers and 16 snorkellers, were identified and analysed. Of the 40 scuba diving deaths, 12 had clinically significant medical conditions. Research of diving practices and other factors that might contribute to these deaths allows trends to become apparent. It is accepted that diving fatalities are uncommon, but the fatality rate is unknown in New Zealand because the 'denominator', the number of dives undertaken each year, is unknown.

Introduction

In New Zealand (NZ), drowning remains the third most common unintentional cause of death due to injury, and the rate is higher than in many comparable countries.[1–3] Of all drowning deaths, those related to diving are uncommon, contributing approximately 5% (5–10 deaths per year). The investigation of an accident or death during water activities, especially underwater diving, is greatly hampered by the fragmented and incomplete records. Greater understanding of the circumstances and causes of diving fatalities could result in a reduction of morbidity and mortality among those who dive for recreation or occupation.

Risk factors can be grouped into those that result from aspects of individual divers (level of experience, medical history, alcohol/drug use), equipment problems, environmental hazards, faulty technique, and rescue and resuscitation complications.[4] Fatalities often result when a 'chain' of errors occurs. Previous studies have relied on retrospective audit of case series, culminating in broad recommendations.[5–11] With a diving fatality being an uncommon though devastating event, retrospective qualitative studies can yield detail about causative factors which may be useful in formulating recommendations aimed at reducing the death toll. Prospective studies are difficult to implement and unlikely to yield more useful information that will impact upon the aim of improving the safety of all aspects of diving.[12]

Diving fatalities in NZ waters for the period 1980 to 2000 have been reported.[7] The present retrospective review of diving-related fatalities covers the period January 2000 to December 2006. The year 2000 was included as review of cases in that year was incomplete in the previous report.

Methods

Application for ethics approval was initiated but the author was advised by the Chairman of the University of Auckland Ethics Committee that this was not required as all data used in this retrospective study were already in the public domain. Cases were identified from various sources. Water Safety New Zealand (WSNZ) maintains a database of drowning-related deaths (Drownbase™) and access was sought and approved. A spreadsheet of all known underwater-related drowning deaths from 2000 onwards was provided. The spreadsheet had 23 fields for each deceased person, the following headings being used: date of death, inquest number, family name, given name, date of birth, age, residence region, location region, site (km from shore), activity (scuba, snorkel, or free diving), purpose, ethnicity, gender, status (NZ resident or other), medical condition, fatalities (single or multiple), alcohol, rescue, resuscitation, buoyancy, and a brief synopsis of events. The individual files of the diving-related sub-group were fully examined.

Another source was coroners' reports; the Tribunals Division of the Department of Courts in Wellington was visited to examine the file information held for each identified case. The paper files of all finalised coroner's inquests are stored at that site. A search of the Coronial Index Registrations database allowed identification of diver fatalities. To ensure all police reports were examined, the National Police Dive Squad base was visited to examine the files held there. Further collateral information was sought and obtained from the accident investigator of the NZ Underwater Association (NZUA). Newspaper articles were also obtainable for a few of the cases. For diving-related deaths more data fields were necessary to capture specific factors: the methodology of Davis et al was followed, giving a total of 30 fields.[7]

Figure 1
Annual diving fatalities in New Zealand

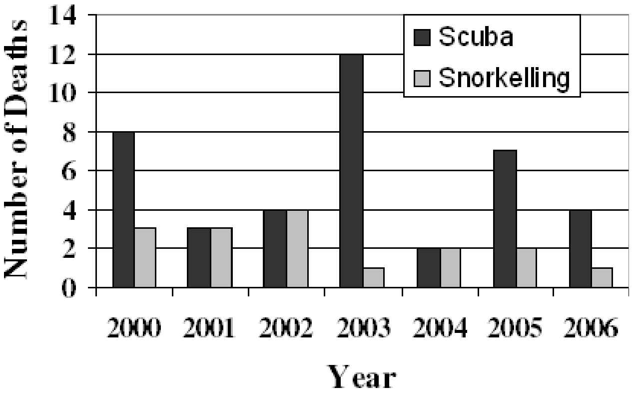
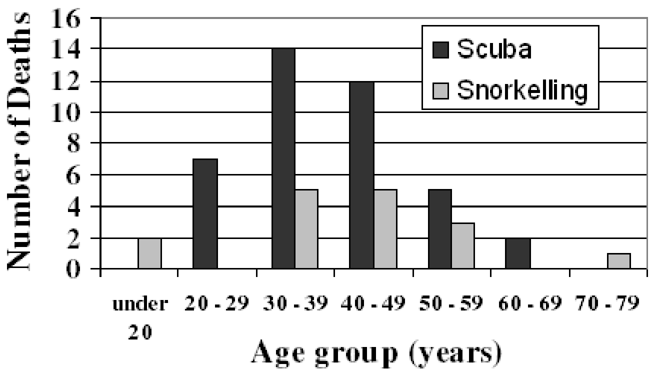


Figure 2
Number of fatalities by age group and type of diving



Results

The majority of cases listed 'drowning' as the main cause of death. Drownbase™ provided 45 cases of diving-related fatalities from 2000 to 2006 inclusive. Individual deaths included in Drownbase™ must be due to drowning, as concluded by the Coroner, otherwise they are discarded. Of the 45, 28 were scuba divers, 14 snorkel divers, and 3 classified as free divers. For example, a cause of death of arterial gas embolism would not be included in Drownbase™. The case of one 59-year-old snorkel diver was discarded by the author because, although he intended to go snorkelling, he was found dead above the high-water mark (a coroner's inquest was not held). Further information was obtained from the Accident Investigator for the NZUA (Taylor L, personal communication, 2006), who had identified eight scuba diver deaths that were not listed in Drownbase™. The National Police Dive Squad formally investigates deaths if the body is found. Their reports were reviewed for additional information on individual cases. A further four scuba divers were identified from police and media records. In total, 40 scuba diver and 16 breath-hold diver fatalities were identified for the period 1 January 2000 to 31 December 2006.

NUMBER OF FATALITIES

For scuba diving the number of fatalities each year ranged between 2 and 12 divers, with a mean of 5.7. Breath-hold diver deaths were steady between 1 and 4 per year (mean 2.3, Figure 1).

DEMOGRAPHICS

The snorkelling group combines snorkellers and free divers, as the use of these terms was poorly defined, the majority of snorkellers being seafood collectors with some incorporating free diving in the process. The age groupings of the fatalities are shown in Figure 2.

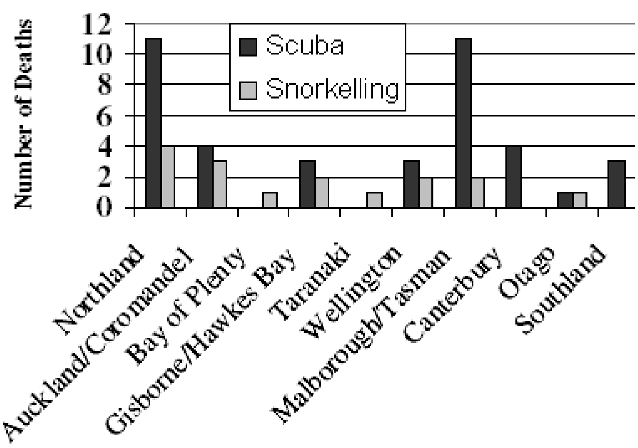
The mean age of the scuba divers was 39.6 years (range 21 to 69 years), and of the breath-hold divers 42.9 years (range 18 to 78 years). Only five (12.5%) of the scuba divers were female (case numbers SC 00-03, SC 00-04, SC 03-06, SC 03-12, SC 05-01), and all breath-hold divers were male.

Thirty (75%) of the scuba divers were of European ethnicity, and of the other 10, seven were Maori, one Polynesian islander, one Japanese, and one was not defined. However, amongst the breath-hold divers the majority (nine, 56%) were Maori. All diving fatalities occurred in the sea. The geographical regions in which deaths occurred are shown in Figure 3.

DIVING EXPERIENCE

Of the scuba divers, 20 (50%) were inexperienced, using the criteria of less than two years' diving.[1] No internationally agreed definition of experience exists. Dive-training certification was confirmed or highly likely for 31 divers, and not available for six. The remaining three divers were untrained. Although some divers had been certified for many years, the infrequency of their diving put them at greater risk.

Figure 3
Fatalities by geographic region of New Zealand



SCUBA DIVING PRACTICES

All the cases involved open-circuit air breathing except for one technical diver (SC 05-05) using closed-circuit rebreather apparatus. There were no fatalities in divers using surface-supplied breathing apparatus (SSBA).

Of the 40 scuba divers, 11 were solo divers, and in 13 other cases buddy separation had occurred, that is, only 16 (40%) were following standard safe diving practice and diving with a buddy at the time of the accident. Seafood collection was the main reason for scuba diving, and would be a factor in buddy separation or the choice to dive solo. Four of the divers were wreck diving, including two female tourists on dive charters.

Three divers were documented to have run out of cylinder air. This may have been a factor in other cases as the assessment of cylinders is dependent on their early retrieval and inspection by experienced divers or the police. Only one diver had released their weight belt and four divers were overweighted.

Death was related to dangerous sea currents in the triple fatality in 2000 (SC 00-01, SC 00-02, SC 00-03), and in the death of SC 05-06. In another case (SC 00-07) the sea swell is likely to have caused one diver to sustain a head injury on rocks and drown; exhaustion due to the swell would be a contributing factor in several other deaths due to drowning, especially shore-based dives.

BREATH-HOLD DIVING PRACTICES

Solo diving was a common factor in the 16 deaths in this group. Seafood collection was the reason for breath-hold diving in 14 of the cases, and drowning was the universal autopsy finding and coroner's verdict. In four cases it is likely that underlying cardiac disease contributed to the death. In one case (BH 04-02) an epileptic seizure is the probable cause of drowning. One diver was struck by a boat, which resulted in loss of consciousness due to head injury and subsequent drowning; another appears to have sustained a head injury on rocks in rough seas and drowned. Two cases of hypoxic blackout, aggravated by previous hyperventilation or ascent, occurred with drowning.

RESCUE AND RESUSCITATION

Rescue and resuscitative efforts are difficult to quantify and interpret. Vigorous and prolonged basic cardiopulmonary resuscitation (CPR) was performed on some cases; in one other case no resuscitation efforts were made despite timely retrieval onto the boat.

AUTOPSY PROCEDURES

Five bodies of scuba divers were not found. In a further three cases there were delays of 12 hours or more in body recovery, thereby limiting autopsy findings due to decomposition and to tissue erosion by sea creatures, such as sea lice. Most of the autopsies appeared to follow the guidelines of the Royal College of Pathologists of Australia, although this was not specified. Those performed in the major cities were done by specialist forensic pathologists. The pre-autopsy use of CT imaging versus plain radiography versus no imaging probably reflects the ready availability of the service; it is site dependent.

CAUSES OF DEATH

Of the 40 scuba diving deaths, 12 (30%) had significant medical conditions that may have disqualified them from diving (Table 1). Another experienced diver had evidence of myocarditis on autopsy implying sudden cardiac death as a cause (coroner's inquest yet to be held). Arterial gas embolism was recorded as the cause of death in nine cases, with a possible tenth case (SC 02-01 – delay in body recovery).

Table 1
Scuba divers with clinically significant pre-existing medical conditions

CASE	Age	Medical condition
00-04	58	Neurologic – recent unexplained syncopal episode
00-06	29	Respiratory – old tuberculosis and dense pleural adhesions
01-03	47	Neurologic – massive cerebrovascular accident
02-02	68	Cardiac – coronary artery disease, type 2 diabetes mellitus
02-03	34	Cardiac – cardiomegaly, myocarditis, coronary artery disease
03-03	69	Cardiac – coronary artery disease
03-04	30	Gastro-intestinal – Crohns disease, on medication
03-07	34	Cardiac – severe coronary artery disease
03-09	41	Cardiac – coronary artery disease
05-01	53	Neurologic – migraine medication (sustained gastric rupture)
05-03	55	Cardiac – symptomatic coronary artery disease 6 years
06-03	53	Respiratory – pleural adhesions; also patent foramen ovale

Two divers died from severe head injury sustained when struck by boats – one was a scuba diver, the other a breath-hold diver, but neither had a visible 'diver below' flag or a buddy. One experienced diver was killed when struck by the tail of a whale. Another diver died from carbon-monoxide contamination of his air cylinder.

Fatality case summaries: scuba diving

SC 00-01, SC 00-02, SC 00-03

Triple scuba diving fatality, students on a Master Diver course attempting a 30 msw drift dive rapidly dragged in a strong ebb tide to 92 metres' sea water (msw).
Cause of death: Massive arterial gas embolism and drowning in two cases; third deceased not recovered, presumed accidental drowning.

This tragedy, in which, as well as the three deaths, three of four survivors suffered decompression sickness, will be the subject of a separate detailed report as it was by far the worst diving accident in New Zealand diving history.

SC 00-04

Poorly conditioned diver with a medical history of chest pain and a unexplained syncopal episode, drowned after a sudden loss of consciousness at a depth of 18 msw.
Cause of death: Unexplained loss of consciousness resulting in salt-water aspiration and drowning, with arterial gas embolism secondary to pulmonary barotrauma sustained during a rescue ascent.

This 58-year-old female had a history of chest pains associated with breathlessness and a previous episode of syncope in a pool approximately one year earlier (possible transient ischaemic attack). She was an inexperienced diver, on her ninth dive since completing her open water diver certificate, although a competent swimmer. With an experienced dive buddy and in calm sea conditions, she initially was underweighted and they ascended from 6 msw to add more weight, then descended again. At 18 msw her buddy noted her regulator appeared partially dislodged and then twice fell out of her mouth. She stopped swimming, and appeared to cease breathing, with a small stream of bubbles exiting past the mouthpiece. Her buddy inflated her buoyancy compensator device (BCD) and brought her to the surface. Resuscitation was attempted. CT imaging prior to autopsy showed widespread cerebral and systemic vascular air embolism. Autopsy showed aspiration of sea water and widespread gas embolism from pulmonary barotrauma. Her equipment was in good condition.

SC 00-05

Experienced diver in good condition, apparent drowning soon after ascent.
Cause of death: Arterial gas embolism.

This healthy, 49-year-old male with 25 years of diving experience had not dived recently. He was on a dive charter boat in calm conditions. His buddy was his 14-year-old son, inexperienced and on his first dive since gaining his open water certificate. Diving as part of a group of six divers, they decided to ascend after one diver ran low on air. The deceased still had 1,150 psi of air in his tank. Upon surfacing, they started to swim into the current towards the boat but soon were tired and initially had to rest on the rocks. The deceased was slower and buddy separation occurred. The deceased was found floating face down in the sea without his mask and snorkel. Weight belt was still worn. After a difficult retrieval, no pulse was palpable but no resuscitation attempt was made (doctor and nurse present). CT imaging prior to autopsy the next day showed probable gas embolism.

Autopsy showed arterial gas embolism of the right carotid artery and aorta. Lungs were congested. Police inspection of the diver's equipment found no faults. The Coroner noted the lack of resuscitation efforts and proper seamanship (the skipper had also dived, leaving the boat in the control of an unqualified person).

SC 00-06

Inexperienced student, first dive since open water course, using hire dive gear, history of lung disease.
Cause of death: Drowning.

This 29-year-old male had limited English and had completed an open water course in New Zealand two months earlier. He had a history of pulmonary tuberculosis as an infant. However, his dive medical was not written in English and he had not documented his history of lung disease. With an experienced buddy, this was his first dive since his course. They planned to dive to 15 msw depth. Three to five minutes after descent the deceased inflated his BCD and rapidly ascended despite efforts by his buddy to slow his ascent. He complained that his mouthpiece was leaking water and he had difficulty clearing it. His buddy surfaced and checked the regulator but found it functioning normally. The deceased switched to using his spare regulator, but appeared uncomfortable with the placement and required his buddy to show him how to place the mouthpiece into his mouth. The deceased wanted to rest for five minutes before they descended again. As with the first descent, the deceased was too buoyant and required his buddy to assist him to descend through the first 2 msw. On the bottom, at a maximum depth of 15 msw, they signalled 'OK' to each other and started exploring for seafood. Regular buddy checks were done. About 15 minutes into the dive, the buddy, who was leading the dive, could not see the deceased. Within a maximum time of 15 seconds he then located him in an unconscious state, lying on his side on the bottom. His regulator mouthpiece was not in his mouth, and bubbles were being expelled. The buddy tried to insert his own mouthpiece and spare mouthpiece into the deceased's mouth but trismus prevented this. He ascended rapidly dragging the victim with him. On surfacing, the victim was unresponsive and making gurgling noises. CPR was immediately attempted but not effective. On shore, with the aid of passing travellers, CPR was continued for 30 minutes until a local doctor confirmed his death.

Autopsy showed dense old adhesions obliterating the right pleural cavity, with right upper lobe volume reduced. Both lungs were consistent with drowning. Microscopy showed localised barotrauma with interstitial emphysema in the right upper lobe only.

Police inspection of his equipment found no faults. His weight belt (9.7 kg) was not dropped during the rescue. The computer showed a rapid ascent warning.

SC 00-07
Well-conditioned diver in rough sea conditions who sustained a closed head injury and probable loss of consciousness leading to drowning. Shore dive.
Cause of death: Drowning secondary to a closed head injury.

This 32-year-old male was undertaking a shore dive with a buddy. He possibly had a history of untreated high blood pressure. The sea conditions were poor. Shortly after entering the water the pair decided to abort the dive due to poor visibility and rough swell. During the swim to shore they became separated by a line of rocks. The deceased was seen about 60 m from shore, floating face down and unresponsive. A local resident retrieved the deceased who was found with his mask off and scuba equipment floating beside his left leg. Once on shore, CPR was unsuccessful.

Autopsy showed a left-sided head injury with an 8 cm deep scalp contusion and skull fractures of the parietal bone and base of skull. He had associated facial abrasions. The Coroner noted the lack of regulation regarding teaching of CPR during scuba diver training and the importance of the buddy system. No equipment faults were identified.

SC 00-08
Well-conditioned, experienced diver in a group searching for seafood.
Cause of death: Uncertain – body not recovered.

This 33-year-old male had obtained a PADI Advanced Diver Certificate three months earlier and dived regularly since. He was on a club boat trip with eight other divers. On the trip back from the main dive site, four of the divers dived for scallops at 22 msw. Three divers, including the deceased, dived together. During the 30-minute dive, the deceased appeared "OK". He had passed his catch bag to a buddy for tying to a float line, and signalled he was ascending. The remaining air in their tanks was sufficient for a controlled ascent. The deceased did not surface. A surface search was undertaken and a call for assistance was made after 55 minutes. The body was never recovered. The police report noted poor logging of the details of previous dives by the club members, the failure to mark the place of the dive (the float had been retrieved), and the delay in alerting search and rescue services. From the information available the dives undertaken that day would have necessitated decompression stops, raising the possible scenario that decompression illness could have occurred. He was using equipment only seven months old.

SC 01-01
Well-conditioned diver, ascent from scallop dive, swimming back to boat, then loss of consciousness, dive cylinder empty.
Cause of death: Arterial gas embolism.

This healthy, 40-year-old male was an experienced diver. He was diving with a buddy for scallops. His ascent to the surface appeared trouble free, but he then lost consciousness within a few minutes. On inspection his tank was empty.

No autopsy report was available, however the Coronial Index registration states the cause and circumstances of death as '*cerebral arterial gas embolism which happened either whilst diving or immediately after surfacing from diving*'.

SC 01-02
Experience diver with cerebrovascular disease on medication.
Cause of death: Massive brain infarction secondary to severe atherosclerosis.

This 47-year-old experienced diver had a past medical history from his general practitioner indicated that he likely suffered transient ischaemic attacks for over two years prior to his death. He was treated for hypertension, but medication (felodipine, inhibace, aspirin) compliance was variable. He was an ex-smoker. He had a family history (father) of cerebrovascular disease. Four months earlier he had been seen by a neurologist and an MRI was requested, but he missed the appointment. On this dive he was accompanied by three other people, but diving solo. He was diving to a depth of 25 msw for about 15 to 20 minutes and apparently ran out of air. He surfaced, swam back to the boat and initially appeared well but then deteriorated on board. He was transported to hospital and underwent recompression treatment, but died three days later. A CT scan of his brain showed new infarctions and an old cerebrovascular accident. Autopsy showed severe brain infarction secondary to pre-existing severe atherosclerosis. Death was most likely due to stroke secondary to atherosclerosis rather than cerebral arterial gas embolism. His equipment was poorly maintained. His BCD was old (pre-1985) without an automatic over-pressure valve. His dive cylinder was out of date, with a worn O-ring. He was not overweighted (8.7 kg).

SC 02-01
Experienced diver, no buddy, descended to 30 msw to free an anchor, but did not surface, body found four days later.
Cause of death: Drowning, possible barotrauma.

This healthy, 35-year-old male was experienced (PADI Advanced Open Water, 1993). His near-new equipment was purchased in November 2001, but on the fatal dive he had a borrowed weight belt and was overweighted

(12 kg). His computer was not turned on for these dives but when analysed the log showed he had violated ascent rates on all previous dives. He was diving alone. This day he wanted to retrieve his boat anchor lost the day before. He undertook several descents, surfacing after 10 minutes to get a speargun, then returning it to the boat and diving for another 10 minutes to 22–24 msw to successfully find his lost anchor rope. Then he descended again to free the snagged anchor of a neighbouring boat at 31 msw depth. He did not surface. The body was found at depth four days later by a search-and-rescue team. He was still wearing all of his equipment. His autopsy showed drowning but decomposition prevented definitive diagnosis of barotrauma and gas embolism. The police report confirmed he was overweighted, had probably run out of air, had a history of rapid ascents and unsafe diving practices (including previously running out of air), and was at increased risk of decompression illness. He did not release his weight belt. The Coroner emphasised the complacency and human error in this case.

SC 02-02
Experienced diver, not dived for five years, poorly maintained equipment, solo dive, recent treatment for cardiac disease.
Cause of death: Arterial gas embolism.

This 64-year-old male reportedly had 15 to 20 years of diving experience, but had not dived in the past five years. He was on medication, including metformin for type 2 diabetes mellitus, and simvastatin for dyslipidaemia. On this dive, he was with two other divers, but was solo diving to 13 msw for 23 minutes. His equipment was poor, with the BCD missing a toggle from the rear dump valve, putting him at risk of rapid ascent. He was seen by the boatman to surface, dive again, and resurface three minutes later in an unresponsive state. He had not jettisoned his weight belt. Resuscitation was attempted with the deceased still in the water. He was retrieved into the boat with difficulty once the other divers returned after 5–10 minutes. Unsuccessful CPR continued until after they reached the shore. He had not run out of air (tank pressure 1,400 psi).

Cause of death at autopsy was arterial gas embolism; the lungs were heavy and drowning was likely to be a factor. The coroner's report emphasised the need for regular servicing of equipment, maintaining skills and diving with a buddy.

SC 02-03
Solo diving for seafood, shallow water.
Cause of death: Drowning, patchy myocarditis at autopsy, coronary artery disease and cardiomegaly.

This 34-year-old male was solo diving for seafood in shallow water. He was of large build. His equipment was poorly serviced ("second-hand"), and in cold water he wore a short 3 mm wetsuit and no hood. He was diving for 40 minutes to a maximum depth of 4 msw; he then returned to shore with his catch. On returning to the water he soon got into difficulties. He disappeared below the surface, and was rescued by a snorkel diver who had witnessed his distress. He was unconscious on retrieval from a depth of 1 msw. Resuscitation was attempted. Autopsy showed drowning, coronary artery disease (50% narrowing of the proximal left anterior descending coronary artery), patchy myocarditis, and cardiomegaly (540 g). Police inspection of his BCD showed it to be old and malfunctioning. He had been overweighted (14.5 kg).

The Coroner emphasised the need for regular medical assessments and servicing of equipment.

SC 02-04
Inexperienced diver, at depth of 32 msw, panic, rapid ascent.
Cause of death: Arterial gas embolism.

This healthy, 40-year-old, inexperienced male was diving in calm conditions with eight other divers, two being instructors. He was dive certified in 2000 but had completed only 11 scuba dives in total. He had dived twice the previous day, within decompression limits. After approximately 15 minutes at 27 msw he indicated he had a problem and showed the others his gauges. He had 900 psi of air pressure. He appeared agitated and spat out his regulator mouthpiece. He would not accept a spare regulator from a buddy or an instructor. His mask was full of water and he pulled it away from his face, consistent with panic. Other divers attempted to inflate his BCD but it seemed to be full already. A dive instructor attempted to ascend with the deceased, during which she tried to place her spare regulator in his mouth and operate it. Part way to the surface the deceased and the instructor parted, with the deceased sinking towards the bottom again. At 16 to 20 msw he was caught by two other divers. He had no regulator in his mouth. His weight belt was released and he was brought to the surface. Once on the boat, CPR was started. Some response occurred with a few spontaneous breaths, vomiting and possibly a palpable pulse, but ultimately resuscitation was unsuccessful.

CT imaging prior to autopsy showed cerebral and systemic gas embolism. Autopsy showed pulmonary and systemic gas embolism. Police inspection of his equipment showed that his regulator free flowed easily, and his BCD had a faulty dump valve with two other valves functioning normally. His tank contained 750 psi pressure. He was overweighted with 17 to 20 kg on previous dives.

SC 03-01
Poorly conditioned, uncertified diver, shore dive, no BCD, out of air, exhaustion and panic on swim back to shore.
Cause of death: Asphyxia secondary to drowning.

This healthy, 35-year-old male had stated to his buddy that he had over 20 years of diving experience. His buddy was experienced. They intended to dive for crayfish. He borrowed regulators, two full dive tanks, back pack and weight belt. Importantly he did not have a BCD. The borrowed regulators had been ‘recently serviced’ according to the lender. Pre-dive, the deceased and his buddy checked their equipment. Despite the disapproval of the buddy diver, the deceased threaded his weight belt through his back pack. Sea conditions were a half-incoming tide, no big swell, little wind and overcast sky. Water visibility was 5 to 8 m. The first dive to a maximum depth of 9 msw was uneventful. They rested for half an hour, then re-entered the water with full tanks at 2030 hr. They descended and swam out to a wreck at 6 msw depth, 80 m from shore. After 20 minutes underwater the buddy had 1,800 psi remaining, and the deceased 1,200 psi. They commenced swimming back to shore. The deceased gave a ‘low on air’ signal, so his buddy gave him his second regulator. They surfaced from 6 msw depth as the buddy’s air supply finished. The buddy had his BCD to give positive buoyancy, whereas the deceased had no BCD. With the shore about 100 m away, the deceased rapidly found it hard to swim. Despite being aided by his buddy, who released his own weight belt and helped to support him with his BCD, both were exhausted within 8–10 minutes and were still 50–70 m from shore. The deceased panicked and had his knife in his hand on a lanyard, putting the buddy at risk of injury. The buddy tried to calm him and jettison his tank, but the deceased was lunging with the knife. They separated, and the buddy made it to shore exhausted. The alarm was raised with the police and Coastguard at 2130 hr, now dusk. Two boats were sent to the scene, and conditions by that time were quite rough with a heavy swell, and an ebb tide. The body was retrieved 100 m from shore by boat at 2152 hr. Resuscitation attempts were unsuccessful.

Autopsy gave a cause of death of asphyxia from drowning. His BMI was 36.5 kg.m^{-2}. No alcohol was present but he had a blood tetrahydrocannabinol level of 1.5 mcg.L^{-1} (significance not determinable) consistent with smoking a cannabis cigarette 1 to 12 hours earlier. Police inspection of his equipment confirmed that it was very substandard. His tank was empty. The back pack still had weights attached but his weight belt had been released. He was probably overweighted (13 kg). His regulator was old, modified and in need of servicing as it free flowed. His fins were old and not designed for scuba diving. His wetsuit was also old and unsuitable for the cold-water conditions. The Coroner noted the many errors of planning and judgement.

SC 03-02
Solo diving for seafood, shore dive, heavy weight belt, cylinder detached from BCD, possible asthma, called for help but not found.
Cause of death: Drowning.

This 28-year-old male was inexperienced; he had been certified in 2000 but had not dived for 18 months. He had a medical history of productive cough and use of an anti-asthma inhaler. He was a non-smoker. He had near-new equipment. He was diving with others for seafood but solo at the time of the incident. On his computer a maximum depth of 7.3 msw was logged. The sea conditions were rough. He was seen approximately 30 m from shore. Two calls for help were heard by family members on shore but he could not be located. Police and search-and-rescue personnel were mobilised, and five hours later his body was found amongst kelp but not entangled. The tank had come loose from his BCD and harness.

Autopsy showed asphyxia from drowning in association with mild chronic bronchitis. His BMI was 31 kg.m^{-2}. Police inspection of his equipment confirmed its good condition, including that of his drysuit. His tank still contained 600 psi of air pressure. His computer showed he had not violated dive limits. However, he was overweighted.

SC 03-03
Solo diver in shallow water, found deceased, weight belt discarded.
Cause of death: Ischaemic heart disease associated with atherosclerotic coronary vascular disease.

This 69-year-old male had 20 years of diving experience “off and on”; no record of certification could be found. He had a past medical history of hypertension and type 2 diabetes mellitus, and was on oral medication (metformin, diamicron, felodipine). He was separated from his buddy, diving for shellfish in shallow water (3 msw). After 15 minutes his buddy found the deceased’s weight belt (5.4 kg) and mask on the seafloor and on surfacing found him floating unconscious. CPR was unsuccessful.

Autopsy confirmed coronary artery disease as the cause of death. Police inspection of his dive equipment showed it was old but had no faults.

SC 03-04
Experienced, diving for seafood with buddies, buddy separation.
Cause of death: Not confirmed – body recovered after nine months.

This 30-year-old male was experienced, diving in the same area over the previous five years. At the time he was well conditioned, although he had a past history of Crohn’s disease with an exacerbation 11 months earlier requiring long-term immunosuppressive treatment. With four other divers, he was searching in calm water for crayfish. They dived to 27 msw then ascended to 15–18 msw. His buddy ran low on air and surfaced, leading to buddy separation. The deceased’s bubbles were tracked for about 15 minutes, and then those on the boat concentrated on picking up the other divers who had surfaced. The deceased did not surface and no trace was apparent. Search and rescue was initiated but not successful. Nine months later his body was found at 28 msw depth. Autopsy could not confirm the cause of death. From the position of his body under a rock it is possible he was attempting to catch a crayfish and ran into difficulty.

SC 03-05
Diving for seafood, out of air.
Cause of death: Hypoxic brain injury.

This healthy, 32-year-old male was inexperienced, having completed his PADI open water dive training the previous day. He was on a dive charter with ten other divers to collect oysters. The sea conditions were good. He dived with his buddy to a maximum of 22 msw, but mostly at 16 msw, with good visibility. The duration of the dive was 20 minutes. They ascended as they were low on air, during which time the deceased dropped his catch bag. On surfacing the buddy found that the deceased had not surfaced. He was retrieved from the seabed at 15 msw, and CPR commenced. He was transported to the regional hyperbaric unit but died the next day.

Autopsy showed hypoxic brain injury. Police inspection confirmed the equipment was new and that the cylinder was empty.

SC 03-06
Inexperienced, obese, certified diver, wreck diving, loss of consciousness at 22 msw, overweighted.
Cause of death: Pulmonary barotrauma, unexplained episodes of brain ischaemia.

This healthy, 23-year-old female had obtained her open water certificate two years earlier but apparently had not dived since. She was with 10 other divers and two instructors. Prior to the dive, she successfully completed a diving knowledge review test and a PADI document on safe diving practices. During the trip to the dive site, she had mentioned to a fellow diver that she felt slightly seasick, but she did not vomit. In good sea conditions, about 20 minutes into the dive, she was seen to be slowly sinking at 22 msw depth and when attended by an instructor she appeared unresponsive and not breathing. Her regulator had to be held in her mouth and was purged. She was brought to the surface (9–11 metres per minute as logged on her computer, although its alarm indicated this rate was exceeded for a short time) with manual breaths being initiated by the rescuer. She was lifted into the boat and had a palpable pulse. Her airway was cleared and she appeared to respond by squeezing the hand of an attendant. Oxygen was supplied. During transport back to land she deteriorated, appearing to 'swell up', and spontaneous breathing ceased. CPR was initiated, to which she responded with spontaneous respiration after about five minutes. However, after approximately 10 minutes she ceased breathing again. On shore, she was attended by paramedics, and transferred to the base hospital by helicopter. Advanced resuscitation was undertaken, including intubation, left intercostal catheter insertion, and inotropic support. She died en route to tertiary hospital care.

Chest X-ray prior to autopsy showed massive surgical emphysema; skull X-ray did not demonstrate intravascular gas. Autopsy showed changes due to shock, resuscitation and pulmonary barotrauma. The histology of her brain showed signs of global hypoxia/ischaemia, probably 5–10 days previously, suggesting recurrent events leading to the final episode of syncope. The possibility of a dysrhythmia such as long QT syndrome was raised. Her BMI was 38.2 kg.m^{-2} (weight 86 kg, height 1.50 m). No hire equipment faults were identified. She had been overweighted (14 kg). Air pressure remaining was approximately 1,000 psi.

SC 03-07
Poorly experienced, significant cardiac disease, mask leak and rapid ascent.
Cause of death: Left ventricular failure caused by severe coronary artery disease; arterial gas embolism.

This 34-year-old male was dive certified one year earlier. For his dive medical examination he was referred to a cardiologist because of dyslipidaemia, mild hypertension, and a strong family history of ischaemic heart disease (a brother had a myocardial infarct at age 35 years). He was treated for his risk factors, but did not have further investigations such as an exercise ECG test. He had logged 91 dives. He was on a dive charter and dived with a buddy to 16.7 msw for a duration of 8 minutes. The water visibility was 3 m. At the seafloor, his mask leaked and, despite help from his buddy, he elected to surface. He surfaced rapidly and boarded the boat. His condition deteriorated and he had a cardiorespiratory arrest. Despite CPR, he died before the boat reached shore. Autopsy showed pulmonary oedema and severe multivessel coronary artery disease, with his left anterior descending coronary artery greater than 90% occluded and the right coronary artery totally occluded. He had scarring from an old posterior myocardial infarct. He also had systemic arterial gas embolism. His weight was 79.5 kg, height 1.72 m (BMI 27 kg.m^{-2}). No faults were identified on police inspection of his equipment; his computer logged an ascent violation.

SC 03-08
Experienced diver, struck by the tail of a whale.
Cause of death: Presumed injuries or drowning.

This healthy, 38-year-old, experienced, certified diver died while attempting to free a humpback whale entangled in the rope of a craypot. The sudden forceful slapping of the tail fluke impacted on the area of water in which the diver was last seen and he did not resurface. His body was not recovered.

SC 03-09
Inexperienced, uncertified, solo diver, undiagnosed coronary artery disease.
Cause of death: Coronary artery disease.

This 41-year-old male was inexperienced and not certified, although he had his own equipment. He had a history of dyslipidaemia, but had had no dive medical examination performed. The previous night he had consumed alcohol and cannabis. In calm conditions, he dived solo to a depth of about 5 msw, and after 20 minutes surfaced. He appeared exhausted to his shore companion as he hauled himself onto a rock 10 metres away. During his swim back to shore, he called for help and became unconscious; his companion pulled him from waist-deep water. Resuscitation by emergency services was not successful. Autopsy showed he had likely died from coronary artery disease. Inspection of his equipment showed it was old but functioned adequately.

SC 03-10
Inexperienced, certified diver on a group trip, buddy separation, overweighted, found two hours later.
Cause of death: Drowning.

This healthy, 27-year-old male was one of 14 divers on a boat trip; five of the divers were completing a rescue diver course. He had completed a PADI open water course 14–18 months earlier in 2002, but had dived only about four times since then. His buddy was also inexperienced. In calm conditions, they dived to 11 msw where the buddy had a fin problem and ascended, resulting in separation. It was another 70 minutes before the alarm was raised that the deceased was missing and a search was initiated. Two divers from another boat found his body in 19 msw. The weight belt (13 kg) was still worn, but his mask was missing and his regulator out of his mouth. His tank had slipped down the back pack. Autopsy showed drowning had occurred. Police inspection of his hire equipment showed no faults; there was approximately 2,500 psi remaining tank pressure (giving an approximate dive time of five minutes). He was overweighted with a 13 kg weight belt.

SC 03-11
Experienced but infrequent diver, buddy separation.
Cause of death: Uncertain – body not recovered.

This 35-year-old male was an experienced diver but had not dived in the past year. In good conditions, he was on a dive for crayfish with buddies and was last seen at 5 msw clinging to the boat anchor chain. He signalled he was ascending because of a “gear problem”. His buddies continued with the dive to 22 msw, and after surfacing 20 minutes later they found that the diver was not in the boat. An extensive search by boats and helicopter for five hours failed to find him. His equipment was near new.

SC 03-12
Well-conditioned, certified but inexperienced and infrequent diver, buddy separation, rapid descent as negatively buoyant, ill-fitting fins which came off.
Cause of death: Drowning.

This healthy, 40-year-old female was an infrequent diver since obtaining her PADI open water certification in 1989, having scuba dived only 30 times and not in the preceding six years. Diving with an experienced buddy in good conditions, she used borrowed equipment. No buoyancy check was done. She was seen to descend rapidly from the boat, but her buddy decided to return to the surface from 1.5 msw to get his gloves. He had not communicated with the deceased and buddy separation occurred. No air bubbles indicative of her position were seen by the boatman. A few minutes thereafter her fins floated to the surface. She was found unresponsive on the seabed at 7 msw by a pair of divers who had come to assist in her search. She was still wearing her mask and weight belt, her BCD was not inflated and her regulator was out of her mouth. She was not entangled. Attempt at resuscitation is not known. Autopsy showed drowning. Police inspection of her equipment showed 3,000 psi of cylinder pressure. Her fins were too large for her. There were no equipment faults, but she was overweighted. She probably panicked and did not release her weight belt.

SC 04-01
Experienced solo diver, collecting seafood, hit by a boat when surfacing.
Cause of death: Severe head injury (from a boat propeller).

This healthy, 46-year-old male was experienced and diving in calm sea conditions. He had been diving with two other divers, but was diving solo for scallops at 20 msw. A boat motored over the area in which he was diving and he sustained a severe open head injury causing death. The ‘diver below’ flag was not visible to the skipper of the launch. Autopsy confirmed unsurvivable open head injuries.

SC 04-02
Experienced solo diver, failed to surface.
Cause of death: Asphyxia due to carbon-monoxide poisoning.

This healthy, 35-year-old male was an experienced diver. He was diving alone, telling his boatman he would be diving for only 15 minutes, but he failed to surface. He was found at 9 msw the following day. Autopsy was limited by decomposition and damage from sea lice. Police inspection of his equipment showed a cylinder air pressure of 2,850 psi. The carbon-monoxide analysis was 13,600 +/- 300 parts per million (NZ and British Standards require less than 10 parts per million). Also there were increased levels of carbon dioxide and methane. A second cylinder owned by the deceased and filled at the same dive shop returned a similar analysis. He was overweighted (17.5 kg) and had not released his weight belt. His other equipment had no faults. The Coroner stated that death was due to asphyxia due to his cylinder gas being contaminated with carbon monoxide, “*brought about by an idiosyncratic malfunction of the air-compressing equipment*”.

SC 05-01
Tourist, inexperienced diver with medical problems.
Cause of death: Gastric rupture and arterial gas embolism.

This 53-year-old female passed a PADI advanced open water course in 2004 and had logged 18 scuba dives while in Australia. She had a medical history of previously treated hypertension, dyslipidaemia, and migraine headache (medicated with sumatriptan and prochlorperazine). She took diclofenac for osteoarthritis of an ankle. She was on a guided wreck dive by boat in calm sea conditions. She was with a buddy, another pair of divers and their instructor. She dived to a maximum of 26.5 msw for 24 minutes. During ascent up the shot line to the 5 msw decompression stop, the deceased continued to ascend and was grabbed by her buddy. While decompressing at 5 msw she became unresponsive. She was retrieved onto the boat and CPR was commenced. Resuscitation was unsuccessful and ceased once a paramedic had arrived by helicopter. Prior to autopsy, CT imaging showed significant cerebral and systemic intravascular gas. She had a severe pneumoperitoneum caused by rupture of the stomach, causing upward displacement of the diaphragm. Autopsy showed a 55 mm laceration of the lesser curvature of the stomach. Multiple rib fractures and sternal fracture secondary to CPR were present. Moderate coronary artery atherosclerosis was present. Police inspection of her equipment showed 1,000 psi in her cylinder and no faults.

SC 05-02

Inexperienced, uncertified, solo diver, rapid ascent.
Cause of death: Cerebral arterial gas embolism.

This healthy, 27-year-old man was inexperienced, and not certified (he had failed to complete a PADI open water dive course three months earlier). With borrowed diving equipment he dived alone on a wreck in calm sea conditions. His companion, a female, non-diving partner, remained on their boat. He consumed one beer, a pie and a cigarette half to one hour before the dive. At the dive site he was seen to descend but then surfaced after 10–20 minutes and called for assistance in a distressed state. He lost consciousness, and it took 10 minutes to retrieve him onto the boat with the aid of other boaties. Resuscitation was commenced and he survived to hospital but died four days later. Autopsy findings were cerebral arterial gas embolism secondary to pulmonary barotrauma. A small flap-competent atrial septal defect was found. Police inspection of his borrowed equipment showed a regulator defect with the second stage needing servicing as it was hard to breathe through. The maximum depth on his gauge was 12 msw, although the police inspection report suggested it was probable that he had descended to 25 msw and consumed all his air without locating the wreck he was searching for and then panicked. His cylinder was empty. He had not released his weight belt.

SC 05-03

Experienced, solo diver with a history of heart disease.
Cause of death: Drowning secondary to probable cardiac dysrhythmia. Coronary artery disease.

This 57-year-old male was an experienced diver, first certified in 1984. He had a medical history of angina going back to 1997, for which he regularly visited a cardiologist and had been assessed as having mild coronary artery disease and dyslipidaemia. He was on a six-day boat trip with other divers. The sea conditions were flat calm with good visibility and water temperature of 9^{O}C. The deceased was last to enter the water, his buddy had already descended. He was first to surface 14 minutes later and was seen kicking towards the shore. The other divers surfaced and were picked up by the boat. The deceased was then seen floating motionless on his back; his BCD was inflated, mask on, and weight belt still worn. His catch bag floated nearby. He was blue with froth at his mouth. He was retrieved onto the boat using a cage due to his size. CPR was commenced and emergency services attended by helicopter, but he had died. Autopsy showed a moderately enlarged heart (460 g) with 75% stenosis of the right coronary artery and 70% stenosis of the left anterior descending coronary artery. His lungs were heavy due to drowning, with evidence of gastric aspiration. His weight was 109 kg, height 1.85 m (BMI 32 kg.m^{-2}).

SC 05-04

Experienced diver with buddy, dragged deep in current.
Cause of death: Uncertain – body not recovered.

This 43-year-old male was PADI Advanced Open Water certified three years earlier, and passed specialty dive courses on his way to completing over 100 dives. He was on medication for dyslipidaemia but otherwise well. He was a member of a dive boat charter group and the previous day had completed two dives. He was diving for crayfish in an area known for its treacherous waters; two years earlier two scuba divers went missing but were found alive many hours later. The site was said to be safe for diving at low tide, for 15 to 20 minutes only. The weather was good with a slight breeze of 10–15 knots and good water visibility. In the morning the divers completed one dive on a shipwreck. They then travelled to another site. The deceased and his buddy dived to 33 msw, then ascended to 24–26 msw because of the current. After 12 minutes they were ascending to the surface when they were suddenly dragged deep in a turbulent current to between 50 and 64 msw. The buddy released his weight belt and inflated his BCD in order to ascend to the surface but the deceased did not surface. An extensive search for his body was unsuccessful. His buddy required retrieval for treatment of decompression sickness.

SC 05-05

Experienced, solo diver using rebreather apparatus.
Cause of death: Hypoxia, hyperoxia or hypercapnia, possibly followed by drowning.

This experienced, 48-year-old male was on a boat trip with other divers. He was first certified in 1997 and had passed advanced diving courses, including being trained in the use of his 'Buddy Inspiration' rebreather equipment. He had no past medical history. He dived solo to 'test dive' his new drysuit and collect mussels for fishing. Fifty minutes later he had not resurfaced and a search by his companions found his body at 15 msw. He had not released his weight belt (5.3

kg). An unsubstantiated report suggests he may not have turned on the oxygen supply to his rebreather.

SC 05-06
Buddy separation.
Cause of death: Uncertain – body not recovered.

This 44-year-old male was an experienced diver. He had no past medical history. He was diving with four others. Buddy separation occurred and he did not resurface. His body was never recovered despite an extensive search.

SC 05-07
Inexperienced diver, cylinder valve not fully opened, compounded by buddy separation.
Cause of death: Hypoxia as a consequence of maladjustment of diving equipment.

This 29-year-old male was inexperienced having logged only 14 scuba dives in the seven years since open water certification in 1998. He had undertaken a refresher course in 2005. He had no past medical history. Weather and water conditions were excellent. He was diving for scallops with five companions, two of whom also dived. Buddy separation occurred. He did not surface. Search and rescue was initiated. His body was found the next day at 18.2 msw, attached to a full catch bag and weight belt (13.2 kg) still in place.

Autopsy was limited by damage due to sea lice and decomposition. Police inspection of his equipment showed the tank valve was opened only a quarter turn and the regulator's performance was reduced. The tank contained 1,470 psi air pressure.

SC 06-01
Diving from shore for crayfish.
Cause of death: Drowning.

This 37-year-old male was diving from shore for crayfish and seafood. His certification and experience are not available. He had no past medical history. The conditions were good with calm seas. He failed to surface and his body was found by a search team two hours later.

SC 06-02
Experienced, solo crayfish diver who ran out of air.
Cause of death: Hypoxia.

This healthy, 41-year-old, experienced diver was certified in 1982, and had done at least 30 dives in the preceding two years. In good conditions, he went by boat for a crayfish dive with one companion. He did not surface after 25 minutes and his boatman raised the alarm. His body was found by the Police Dive Squad the next day at 25 msw. He had 25 crayfish in his catch bag, which was secured to him without entanglement. Police inspection showed his equipment to be relatively new. The weight belt (10 kg) was not released. His cylinder was empty.

SC 06-03
Poorly conditioned diver, rapid ascent and cardiac arrest when swimming to shore.
Cause of death: Arterial gas embolism, patent foramen ovale, old pleural adhesions.

This 53-year-old male's diving experience is unknown. He was said to have had two 'heart attacks' eight years previously, but was not on any regular medication. There was no documented recent dive medical examination. He was diving with three others approximately 40 m from shore. He surfaced after 30 minutes due to a 'BCD problem' and while swimming to shore lost consciousness. Resuscitation was commenced by his companions and continued by ambulance staff, but he died. Prior to autopsy, CT imaging at 18 hours showed extensive intra-arterial gas in the cardiac chambers and aorta. No cerebral intravascular gas was seen.

Autopsy showed arterial gas embolism. There were old pleural adhesions and mild emphysema, a patent foramen ovale (6 mm probe patency) and no evidence of myocardial infarction.

SC 06-04
Experienced diver with buddy, uneventful dive, sudden loss of consciousness and submersion when on surface.
Cause of death: Drowning, myocarditis (inquest yet to be held).

This 55-year-old male diver was an experienced diving instructor. He had no past medical history. On a dive charter with other experienced divers, he surfaced from 32 msw with his buddy, and was preparing to exit the water (he had removed his mask) when he sank. Attended by his buddy he was poorly responsive and she could not manage to bring him to the surface. He sank to the sea floor at 32 msw, and was rapidly retrieved (weight belt released) to the surface by another diver. Resuscitation was attempted. Autopsy showed drowning and myocarditis. The equipment inspection report is awaited, but initial assessment is that there were no faults.

Fatality case summaries: breath-hold diving

Information on the breath-hold diver deaths was generally very limited and, therefore, this is summarised in Table 2.

Discussion

Since the publication of the work of Davis et al the average number of diving fatalities in NZ waters each year does not appear to have altered. For the period 1980–2000, the estimated minimum scuba drowning rate was 5.8 deaths per 100,000 divers per year.[7] For the present series, if we make the same assumptions for the number of active scuba divers in New Zealand, the mean rate of scuba diving fatalities was 5.7 per year. The number of dives performed each year in New Zealand waters is unknown, and there is no system for collecting information on the number of cylinder fills.

Because these were both retrospective, documentation-based surveys, and follow-up investigations from family, diving associates and general medical practitioners were not undertaken, all figures are likely to be underestimates. Another criticism leveled at this type of study is that there is often inadequate information, and over-interpretation of the data is the rule with repetition of dubious statistics (Edmonds C, personal communication, 2007). The case analyses should be undertaken by at least two independent assessors (which was not the case here), who then reach a consensus diagnosis. Otherwise, individual prejudices are inevitable, as seen with the invaluable but flawed analyses in Project Stickybeak, for example.

It has long been claimed by the diving industry that the fatality rate is very low for recreational divers, estimates being 2.0–2.9 per 100,000 divers per year. These figures for 'active divers' often assume that divers have only one basic qualification for ocean diving, and do not account for the extremely high incidence of 'drop-out' following certification. This factor magnifies the denominator appreciably and reduces the apparent incidence. Monaghan's analysis in 1989 of PADI data gave a higher rate of 20–30 fatalities per 100,000 'active divers' per year.[13] Unreliability of the denominator data is mostly overcome by the British Sub-Aqua Club, which recorded 39 diving deaths amongst members (average membership 38,712) during the 2000–2006 period, giving a death rate of 14.4 per 100,000 divers per year.[14] This involved one of the best trained and disciplined recreational diving organisations. In those countries that collect more specific diving data, recreational scuba death incidences per 100,000 diving days or 100,000 dives were reported as 2.9 and 2.05 respectively.[5,12] Based on an assumption of 10–15 dives or diving days per year for active divers, this is consistent with a death rate of 20–30 deaths per 100,000 divers per year.

It is apparent from this type of case series that the aim of many divers is the collection of seafood. Many divers (how many is unknown) do not obtain formal certification to dive, learning from family or friends. Cylinder fills can be purchased for the non-certified by the certified friend or family member. Familiarity with the fill station staff can allow a scuba diver to obtain fills for many years after they have passed their dive course, ignoring the ravages of time on their dive competence, and medical and physical fitness.

Lack of medical conditioning or fitness for diving has been highlighted previously by Acott.[15] In the present case series, 12 divers had conditions that would have disqualified them from scuba diving, either forever or until further investigations had been performed. For want of attending a competent diving medicine physician some of them might be alive today, pursuing less risky recreational pastimes. As Acott and others have pointed out, the exertional demands of scuba diving can be great, exceeding 12 times the normal metabolic rate. Water conditions can change rapidly, calling on all the physical attributes of a diver to survive whist trying to avoid the added burden of panic.

Two tourists, both female (SC 03-06 and 05-01), died while on supervised scuba diving charter trips. Both were diving on the same attractive, but not necessarily easy, open water wreck. Interestingly one had an uncommon problem of gastric rupture. This complication has been described previously.[15–17] The cause of death of SC 03-06 was drowning but the possibility of an underlying cardiac cause of syncope could not be established. Her BMI of 38 $kg.m^{-2}$ may have been an important factor.

Solo diving and buddy separation remain the standout features of this case series, as with other published series. Coupled with inexperience, the likely outcome for the diver is drowning precipitated by panic and exhaustion, and sometimes pulmonary barotrauma and arterial gas embolism. Poorly managed underlying medical conditions also feature. There is little safety margin in diving, that comes only with following the well-established guidelines that are regularly in the media courtesy of the NZ Underwater Association and the National Police Diving Squad. The buddy system is one of the foundations of scuba diver training; the awareness of improved safety is exemplified by the 'buddy rope' mentioned in dive internet chat rooms, and mandatory for Royal Navy divers if scuba diving (but not on SSBA).

Buoyancy control, or as PADI teaches 'peak performance buoyancy', is another foundation of training in scuba diving. The data are lacking on whether the divers in this case series performed buoyancy checks, but it could be assumed that this was not part of their routine pre-dive check. Four scuba divers were thought by the police inspection team to be overweighted. There was no definite history of weight-belt release by any of the divers, although one scuba diver had possibly dropped his weight belt. Also there was the tragic drowning of a breath-hold diver who had the weight belt catch around his legs while entrapped in kelp in the wash from a large passing boat.

One of the scuba divers had a missing toggle on their BCD – probably not a factor in his death but still reflective of poor equipment maintenance. Regular dive equipment maintenance follows from dive experience, so it is little wonder that some of the divers had equipment faults or buoyancy issues. The scuba diver (SC 03-01) who did not have a BCD and strapped some weights to his cylinder back pack was diving with an 'experienced', multiply 'certified' diver who should not have risked either of their lives by going near the sea that day.

Maori, who account for approximately 10% of the census population of NZ, remain overrepresented at 50% of the snorkellers due to their proclivity for the sea and seafood. Snorkelling without fins is not uncommon in this group of swimmers, but carries the risks of exhaustion and drowning

Table 2. Summary of data recorded in 16 snorkelling

Case	Age	Fins	Weight belt	Wetsuit	Risk factors
BH 00-01	43	Y	Y	?	Solo, no dive flag
BH 00-02	44	Y	Y	Y	Buddy separation
BH 00-03	37	?	Y	?	Solo, overweighted
BH 01-01	39	N	Y	Y	Solo, rough sea
BH 01-02	34	Y	Y	Y	Solo, rough sea
BH 01-03	40	N	Y	Y	Rough sea
BH 02-01	18	Y	Y	Y	Buddy separation
BH 02-02	31	Y	Y	Y	Solo, overweighted, current
BH 02-03	51	Y	Y	Y	Wash from passing ferry
BH 02-04	48	Y	Y	Y	Buddy separation
BH 03-01	54	N	Y	Y	Solo, medical
BH 04-01	47	Y	Y	Y	Buddy separation
BH 04-02	18	?	?	?	Buddy separation
BH 05-01	55	?	Y	Y	Solo
BH 05-02	78	?	?	?	Solo
BH 06-01	78	?	?	?	Rough sea, buddy separation

if sea conditions deteriorate. Comparison with snorkeller deaths in Australia shows similar factors are involved, but the reasons for undertaking breath-hold diving, the sea conditions and the population involved are dissimilar.

Regarding autopsy procedures, it is likely that the RCPA guidelines are followed by pathologists (Koelmeyer T, personal communication 2006).[19] However, it is apparent that the post-mortem reports, which are an integral part, had no standard format. Those written by forensic pathologists stated the need to interpret the examination findings in concert with facts produced by the police investigation, equipment inspection and analysis of the cylinder gas. There is a variation in what imaging is done; the guideline recommends that plain chest X-ray is an erect film and erect abdominal X-ray is also indicated. In many instances supine X-ray is performed, which is less sensitive.[19–22]

As expected, drowning is the terminal cause of death in the majority of inquest reports. As in the DAN data, gas embolism is not uncommonly diagnosed as the primary cause of death, and we know that the inexperienced diver who panics may then suffer gas embolism due to a rapid, uncontrolled ascent. The teasing out of the sequence of events in each fatality can be difficult and in some cases it remains unknown due to lack of collateral history.

Delayed body recovery from the sea rapidly decreases the utility of an autopsy, as destruction by sea lice and other creatures is compounded by decomposition exacerbated by

deaths in New Zealand, 2000–2006 (? – no data recorded)

Comment	CPR	Significant medical history	Cause of death
Hit by boat	N	–	Drowning, head injury
Shallow (7 msw)	Y	?	Drowning
Shallow (5 msw)	Y	–	Drowning
Caught in current	Y	–	Drowning
–	N	–	Drowning
Panicked	Y	–	Drowning, head injury
Likely hypoxic blackout	Y (delay)	–	Drowning
Likely hypoxic blackout	N (delay)	–	Drowning
Caught in kelp, weight belt caught around legs	Y	–	Drowning
Shallow	Y	–	Drowning
Shallow (4 msw)	Y	Severe coronary artery disease, obesity	Drowning, likely primary cardiac arrest
Shallow, 'safe beach'	Y	–	Drowning
Shallow (2 msw), outdoor education course	Y	Epilepsy	Drowning
Shallow (2 msw)	Y	?	Drowning
Shallow (1–2 msw)	N	Coronary artery disease	Drowning, likely primary cardiac arrest
–	Y	Unspecified medical problems	Drowning

warm environments and wetsuits. Centralisation of autopsy services would improve the accuracy of reports but needs to be balanced against increased delays.

National Police Diving Squad investigations start on the water at the accident site and progress through to full testing of all the available dive equipment, in order to provide a full report to the Coroner. Documentation of diver certification and experience is sought, as well as expertise from manufacturers overseas to retrieve accurate dive profiles from computers, etc. The reports finish with recommendations about diving practices, which the Coroner always includes in the verdict.

This case series, like all others, demonstrates that many diving fatalities are avoidable. Despite continued education on safe dive habits by NZUA, Water Safety NZ, dive training agencies, and the National Police Diving Squad,[23] and the reporting of coroner's verdicts, there has been no reduction in the number of deaths in NZ waters. The analysis by DAN of diver injuries (Project Dive Exploration) and fatalities is being extended to other areas of the world including the Asia-Pacific region, which will improve the ability to compare data from different regions as the methodology will be the same. However, local knowledge is a must and accurate information gathering during the period immediately after the accident is crucial to drawing conclusions about causation at a later date. With more knowledge, improvements in the education of divers about basic resuscitation can be implemented, especially for commercial dive trip operators.

In reality, the only good fatality rate is zero, six deaths per year are six too many. It is obvious from many studies that those with medical conditions would not be diving if they had received a full medical assessment and been advised of the risks. That they wish to dive reflects a positive life attitude, making it even more tragic when their death by drowning or gas embolism has been precipitated by a potentially treatable condition such as coronary artery disease.

More emphasis is being placed on fitness for diving and its evaluation. The diver with, for example, asthma, diabetes, or obesity should preferably have their dive medical examination performed by a qualified medical practitioner. These examinations should not be a 'one off' prior to the first open water course, but a regular ongoing feature of participation in recreational diving. Then the diver can be made aware of the risks of underwater diving and make their own sensible, informed decision.[24]

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Diving expedition medicine – the Coral Cay Conservation experience

Karen E Richardson

Key words
Travel medicine, health surveillance, medical conditions and problems, epidemiology, medical kits, operations – diving

Abstract
(Richardson KE. Diving expedition medicine – the Coral Cay Conservation experience. *Diving and Hyperbaric Medicine*. 2007; 37: 189-97.)

Objectives:
1 To identify the most commonly encountered medical presentations in the setting of a remote land-based tropical diving expedition.
2 To compare these findings with other styles of wilderness expeditions to determine what role the marine environment plays in aetiology and relative risk.
3 To formulate a strategy of medical risk management and provide suggestions for medical supplies for future diving expeditions of a similar nature.

Methods: Weekly reports and sporadic incident forms held by Coral Cay Conservation were reviewed retrospectively with regard to incident type, category, severity, time off diving, personnel involved and treatments used. Results were presented graphically and incident rates calculated to allow comparison with other published expedition data.

Results: 540 medical encounters were recorded in an 18-month period from a sample representing 82.6% of all reporting weeks. An incident rate of 20.4 medical encounters per 1,000 expedition-person-days was calculated from a total of 26,522 expedition-person-days. The aquatic environment was responsible for 50.2% of all treated conditions, and over half of these were ear infections (26.5% of total), and skin problems (9.6%). Specific diving illness was less common (10.4% of total – mostly ear barotrauma). Land-based illness/injury made up 49.8% of total encounters. The main categories were respiratory infections (11.7%), gastrointestinal (11.3%), orthopaedic/injury (8.1%), foot problems (7.0%), animal/insect bites (4.1%), eye infections (2.4%) and surgical or dental cases (1.7%). Only 3% of all cases were serious and required outside medical attention. The incidence of decompression illness was very low: 0.05 per 1,000 person-dives, (one per 20,000 dives).

Conclusions: The incidence of illness/injury on remote tropical diving expeditions is low and compares favourably with other expeditions. The marine environment was responsible for half of all cases seen. Planning of medical support for diving expeditions requires knowledge of specific diving-related illness such as barotrauma, and capability of treating medical conditions resulting from the aquatic environment.

Introduction

In recent years there has been an increasing trend towards travelling to remote and potentially hazardous places.[1] Remote expeditions, by their nature, entail greater risks and present unique logistical and medical challenges.[2–7] Risks vary considerably according to the environment and activity undertaken and each environment has specific hazards with which it is associated.[1,8–15] Little has been published to help individuals assess the risks of joining an expedition and almost nothing specific to the diving environment.

CORAL CAY CONSERVATION

Coral Cay Conservation (CCC) is a not-for-profit, non-government, international conservation organization that provides resources and education to help restore and manage coral reefs. Expedition staff submit weekly operational reports to CCC headquarters in London. These reports, written prospectively and reviewed retrospectively, form the basis of this study.

Coral Cay Conservation is used as a specific model here and the results of this study must be interpreted in context. On CCC expeditions, self-funded volunteers with recreational scuba training conduct scientific reef surveys. They dive up to six days per week in tropical waters with an aim to establishing protected marine areas that are locally sustainable. Volunteers come from all walks of life and range in age between 16 and 70 years. Anecdotally, the majority are university leavers or gap-year students. The expedition staff (also volunteers) usually comprises an expedition leader, scuba instructor, medical officer and one or more scientific officers. On occasions staff members fulfill multiple roles.

Projects are invited into host third-world countries. They aim to be largely self-contained and to leave a minimal environmental footprint. Basic amenities are crude. Power, fresh water, refrigeration and mainland access are often limited. Suitably qualified locals are employed as cooks, boat drivers and compressor handlers. Expedition members are fed communally, share chores and live on land in dormitory-style accommodation. Measures to protect participants from sun exposure, mosquito-borne infections, foot injuries,

Table 1
Coral Cay Conservation standard no-stop bottom times and maximum depths

	Standard profiles				Computer dives	Night dives
Maximum depth (msw)	18	20	25	30	30	12
Maximum no-stop bottom time (min)	37	29	20	14	37	37
Maximum surface-to-surface time (min)	43	35	26	21	43	43

dehydration, food poisoning, ear infections, diving diseases, alcohol excesses and sexually transmitted diseases are strongly encouraged along with adequate pre-expedition medical preparation and travel advice.

Prior to any new project, CCC officers undertake risk assessments of all new activities and sites. For risk management purposes, CCC defines 'remote' as within one hour of ideal urgent evacuation to the nearest recompression facility. Dive boats carry demand-valve oxygen and first-aid kits. Expedition bases have a minimum 24-hour oxygen supply and carry comprehensive medical stores, including chest drains, procedure kits, resuscitation drugs and intravenous antibiotics.

A conservative set of diving limits and standards are used to minimize decompression risk (Table 1). Strict rules enforce safety-conscious diving practice and one off-gassing day is required each week. Reverse profile diving is forbidden and dive computers are used primarily as depth-time meters. Maximum bottom time is limited to 37 minutes and depth to 30 metres' sea water (msw). Divers must prove qualification to minimum advanced open water level and demonstrate buoyancy competency. Novice divers are trained on site using PADI training systems and tables. Fitness to dive is screened in advance by a qualified diving medicine specialist. Divers are required to carry travel insurance that covers scuba activity.

Coral Cay Conservation requires a doctor on site for diving to proceed. The doctor attends the medical needs of all expedition members and also shares responsibility for public health issues, ensuring adequate fresh water and oxygen supply and maintaining the medical inventory kept on site. Each new post-in is asked to familiarise themselves with local recompression and hospital facilities and check evacuation plans already in place. They should have a minimum of two years' postgraduate clinical experience and six months in emergency medicine. Doctors are strongly encouraged to attend an expedition medicine course and gain familiarity with diving-related illness. Communications are maintained with the UK such that the expedition doctors can seek support and advice from CCC headquarters and/or the Diving Diseases Research Centre, Plymouth.

Aims

An awareness of likely presentations, both land and sea-based, is essential to allow advanced planning of medical support and equipment. The aims of this study are:

1 to define what the medical officer should be prepared to encounter on a remote tropical conservation diving expedition to a third-world country;
2 to compare these findings with other styles of expeditions to see what role the marine environment plays in aetiology, and
3 to formulate a strategy of medical risk management for future diving expeditions of a similar nature.

Methods

The research proposal was submitted to the Research and Development Co-ordinator of the Whipps Cross University National Health Service Hospital Trust. It was determined that ethical approval from the external independent NHS research ethics committee was not required. A single observer (KER) reviewed and interpreted the weekly reports and sporadic incident forms received from all staff over seven project sites in three expedition countries over an 18-month period from January 2005 to June 2006. Reports were written prospectively on site and submitted by e-mail at or near the time of writing. They followed a set format where free-text comments were elicited to a series of prompts. For example, the medical officer responded to: introduction, general health, hygiene, medical cases, areas of concern, supplies, requests and conclusions. Other staff provided information on local conditions and logistics. Reports are held electronically at CCC headquarters in London and data were transferred anonymously as text to an Excel spreadsheet.

Medical encounters were recorded in accordance with categories outlined by the Royal Geographical Society (RGS): gastrointestinal, medical, orthopaedic/injury, environmental, animal, foot and surgical/dental.[2,3] Medical encounters thus comprise all infective and skin conditions other than those pertaining to the gut or feet and all other medical complaints. All traumatic events were included in the orthopaedic/injury category, unless they related to feet. All marine animal encounters were listed under the animal category regardless of body site or mechanism of injury. The environmental category included heat-related illness and all diving-specific conditions. Unlike the RGS papers, eye infections were included in the medical rather than surgical/dental category.

Illness and injury were further subdivided according to severity. Severity was defined as

- *minor* when the medical kit was opened but the participant continued with expedition tasks
- *intermediate* when significant enough to necessitate rest from expedition tasks without requiring outside help and
- *serious* if it resulted in a participant leaving the expedition, or their evacuation, hospital admission or death.

As diving was the primary expedition focus, severity was largely defined by time off diving and, where available, this information was recorded. Data on personnel involved, treatments administered, local events, weather conditions, water resources and sanitation issues were also recorded. No attempt was made to interpret uncertain diagnoses.

Data are presented graphically and using simple descriptive statistics. Medical events were calculated to determine incidence per 1,000 expedition-person-days (EPD), an EPD being one person on one expedition for one day. EPDs were calculated for all personnel at all sites over the entire study period, using CCC database figures for volunteers and weekly reports for staff members. Diving incidence was calculated per 1,000 person-dives, a person-dive being one person doing one dive. There were no data available on dives completed, therefore numbers of dives had to be estimated. On the advice of CCC senior staff this was done conservatively at 7 per diver per week out of a possible total of 13 dives per week. This allowed person-dives to be calculated directly from expedition-person-days.

Results

DATA SET

Between January 2005 and June 2006, over seven expedition sites in three countries, a total of 26,522 EPD were recorded. Data yielded 540 separate medical encounters, 20.4 per 1,000 EPD. Reports were available for 82.6% of all reporting weeks, thus medical encounter rates may have been underestimated by up to 20%. Egypt submitted 100% of reports showing 27 medical encounters for 720 EPD, 37.5 per 1,000 EPD. The Philippines had 263 presentations over 9,905 EPD, 26.6 per 1,000 EPD, with 82.6% of reports available for review. In Fiji 81.2% of reports revealed that 250 people sought medical attention in 15,897 EPD, 15.7 per 1,000 EPD.

MEDICAL CATEGORIES

The medical category dominated presentations with 282 out of the total of 540 (52.2%). Of these 143 cases (26.5% of all encounters) were for ear infections, 63 (11.7%) respiratory tract infections and 52 (9.6%) problems with skin. Sixty-seven incidents (12.4%) fell into the environmental category. There were 61 cases (11.3%) of gastrointestinal upset, 44 incidents (8.1%) of minor trauma or musculoskeletal disruption, and 38 problems (7.0%) with feet, many of which were slow to heal. Overall, animal encounters totalled 37 cases (6.9%). Only 9 cases (1.7%) fell into the surgical/dental category. Figure 1 compares the various medical category encounter rates per 1,000 EPD for the three countries.

Volunteers were affected in 447 cases (82.8%), expedition staff in 61 cases (11.3%) and local employees in 28 cases (5.2%). Four others also sought medical attention. If not clearly stated, the patient was assumed to be a volunteer, hence this category is probably over-represented. Between two and six expedition staff and three or four local staff were located at each site. Volunteer numbers varied between and within sites. Ranges (and averages) included: Fiji 6 to 35 (17), Red Sea 4 to 8 (6), Philippines 0 to 25 (10).

SEVERITY OF PRESENTATION

The severity of presentation was documented in 62.4% of cases. Figure 2 shows the percentage of cases falling into each category. Prescribed rest from diving could extend from

Figure 1
The medical category encounter rates per 1,000 expedition-person-days for the Coral Cay Conservation expeditions to the Red Sea, Fiji and the Phillipines and overall

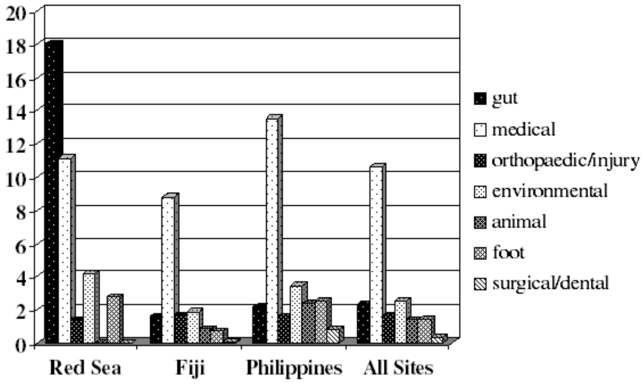
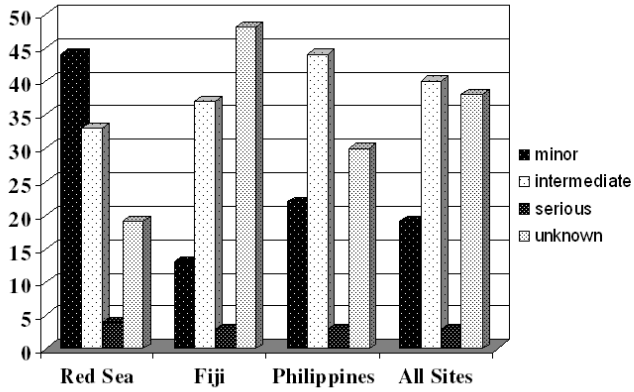


Figure 2
The percentage of cases falling into each severity category of presentation for Coral Cay Conservation expeditions to the Red Sea, Fiji and the Phillipines and overall



one dive to one month, but was most likely to last between one and five days. If time off diving was not documented, extrapolation from similar presentations suggested a predominance of intermediate conditions. Overall, 349 cases (64.6%) needed some time out of the water and 173 (32.0%) were able to continue diving. There were 17 cases (3.1%) that needed outside medical attention or left the expedition and one (0.2%) where diagnosis and severity remain unknown/could not be determined.

SERIOUS PRESENTATIONS

One diver who presented with numbness on her back two hours after an unprovocative dive to 12.9 msw for 38 minutes was evacuated to a chamber as a presumed case of decompression sickness. Full resolution of symptoms occurred following administration of a single US Navy Treatment Table 6 and the participant made an uneventful return to expedition diving one month later. One volunteer with persistent vomiting and diarrhoea was admitted briefly to hospital for intravenous rehydration. Three volunteers (one with a perforated tympanic membrane) chose to leave the expedition early because of recurrent ear problems. Three others sought outside medical review for a persistent ear condition, a skin complaint and a dental problem respectively. One volunteer was dismissed for inappropriate behaviour whilst inebriated. One was assessed in hospital after a series of collapses that were eventually diagnosed as an allergic reaction. Another was investigated locally for severe abdominal pain and repatriated home where he was later diagnosed with an undocumented form of cancer. One was reviewed for an incident that probably represented salt-water aspiration syndrome (SWAS). One volunteer needed an X-ray to confirm his ankle was only sprained whilst one staff member was treated with crutches and rest for two hairline fractures in his lower leg. One local staff member amputated a finger using power tools. He attended a local hospital where the wounds were debrided and closed. Two volunteers sought outside medical attention for reasons that were not made clear in the reports; however, neither of these required urgent evacuation.

PRESENTING COMPLAINTS

Figure 3 shows a more detailed breakdown of presenting complaints, organised to reflect likely aetiology. The aquatic environment was responsible for 50.2% of all treated conditions while land based illness/injury made up 48.8% of total encounters. A total of 215 episodes could be attributed to the marine environment; 39.8% of all medical encounters or 8.1 per 1,000 EPD. The incidence of diving presentations is given in Table 2. Diving incidents totalled 56; 10.4% or 2.1 per 1,000 EPD. An estimation of 21,951 person-dives was made giving a calculated incidence of decompression illness of 0.05 per 1,000 person-dives. The case of possible decompression illness, when retrospectively analysed, probably represents a transient neurapraxia of the lateral cutaneous nerve of the thigh.

Table 2
Incidence of diving presentations by number, and calculated per 1,000 person-dives

Presentations	Number	Incidence
Rapid ascent	1	0.05
Diving incident	1	0.05
Decompression illness	1	0.05
Possible decompression illness	1	0.05
Diver's ear	9	0.48
Middle ear barotrauma	31	1.41
Tympanic membrane perforation	1	0.05
Outer ear barotrauma	1	0.05
Reverse ear barotrauma	1	0.05
Sinus barotrauma	3	0.14
Reverse sinus barotrauma	1	0.05
Sinus unspecified	2	0.09
Barodontalgia	1	0.05
Odontocrexis	1	0.05
Salt-water aspiration syndrome	1	0.05
Total	**56**	**2.55**

There were 186 complaints relating to the ears. Middle ear infections and barotrauma clearly dominate the figures (Table 3). While ear conditions were generally poorly diagnosed, it is interesting to note that the vast majority of cases of otitis externa were unilateral.

TREATMENTS

Treatments were poorly documented, but the majority were provided from on-site medical kits. In all, 686 treatments were reported and those used most commonly (i.e., 1% or more of those documented) are shown in Table 4. Oxygen was required on only four occasions over 18 months. Intravenous fluids and nebulised medications were used on one occasion each. Resuscitation drugs and intravenous antibiotics were not used at all.

GEOGRAPHIC DIFFERENCES IN PRESENTATION

Specific illness patterns were noted for individual sites. The Red Sea project was dominated by gastrointestinal illness owing to an episode of food poisoning affecting all participants. This was the only site where CCC did not control the kitchens. Several expedition staff suffered foot lacerations in Egypt that failed to heal for the duration of their stay. There were no cases of ear infection that prevented expedition members from diving in the Red Sea. Increased salinity was postulated as the reason. In comparison, infective ear conditions clearly dominated at the Fiji (35%) and Philippines (37%) sites. A trend was noted of increased prevalence when precipitation followed long dry spells. The Philippines site, which had greater access to water for washing, had very few skin problems. However, expedition members suffered plagues of mosquitoes after rainfall, possibly owing to standing pools of water on a poorly designed, flat and leaking roof. At the Ravinaki base in Fiji a superficial skin infection of unknown aetiology spread virulently, seeming to coincide with rainfall when the septic tanks were full. This condition was so prevalent it earned itself the nickname “the Rav ming”.

Discussion

In 26,522 EPD only 540 medical encounters were reported. Ninety-seven per cent of these presentations fell into the minor or intermediate categories and on-site medical personnel had sufficient skills and equipment to deal with the situation. The breakdown of severity for CCC is similar

Figure 3
Breakdown of medical encounters by number and percentage arranged according to likely aetiology

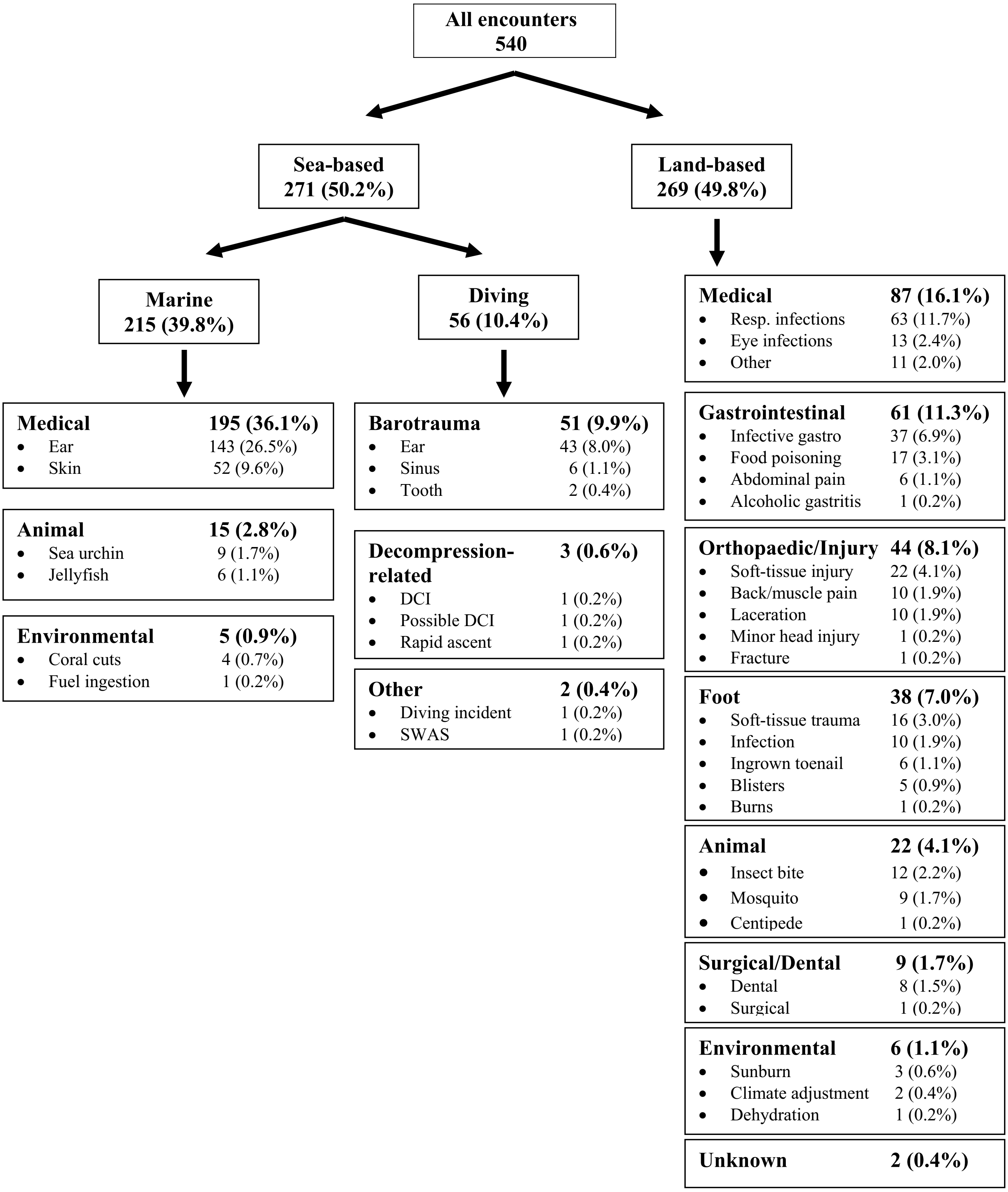


Table 3
Reported diagnoses for ear problems related to diving by number of cases, percentage of total presentations and incidence per 1,000 dives
(**MEBT** – middle ear barotrauma)

All ear conditions	Cases	%	Incidence
Total	**186**	**34.4**	**8.47**
Otitis externa	67	12.4	3.05
Ear – unspecified	46	8.5	2.10
MEBT	31	5.7	1.41
Otitis unspecified	14	2.6	0.64
Diver's ear	9	1.6	0.41
Otitis externa (bilateral)	8	1.5	0.36
Ear – impacted wax	4	0.7	0.18
Otitis media	2	0.4	0.09
Otitis mixed	1	0.2	0.05
Ear – water retention	1	0.2	0.05
MEBT with perforation	1	0.2	0.05
Outer ear barotrauma	1	0.2	0.05
Reverse ear barotrauma	1	0.2	0.05

for serious but almost reversed for minor and intermediate conditions when compared with the RGS data.[2,3] This finding is consistent with what was expected considering the nature of scuba diving. Only 17 cases (3.1%) required outside medical assistance or resulted in participants leaving the expedition and very few of the serious conditions were truly severe. Only one participant was evacuated by urgent means and with hindsight this was probably unnecessary. Thus, participation in a remote conservation diving expedition is not a high-risk activity.

Table 4
Treatments most commonly prescribed (1% or more of those documented) during Coral Cay Expeditions

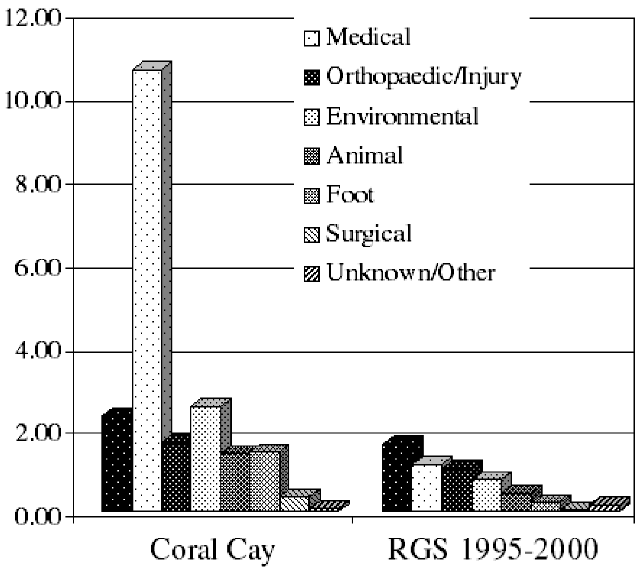
Treatment	Percentage
Ear drops	15.5
Oral antibiotics	11.7
Rest from diving	8.9
Oral decongestants	8.6
Wound-dressing kit	7.8
Wound cleaning	5.7
NSAIDS	5.7
Topical creams	5.2
Rest	5.1
Oral fluids	3.9
Oral antihistamines	3.8
Minor procedure instruments	3.8
Oral analgesia	3.4
Common sense advice	3.0
Betadine	2.6
Minor procedure	2.3
Wound dressing	1.7
Minor injuries treatment	1.5
Eye drops	1.3
Hygiene advice	1.2
Antacid	1.0

A limited body of expedition data exists and comparisons are made difficult by inconsistent denominators.[5,16–25] In addition, study populations, expedition tasks, geographical settings and reporting methods vary widely. Some consistent trends, however, can be seen across many expedition types. The RGS framework was chosen as a template for this paper to allow direct comparison to the largest body of published data on expedition medicine encounters.[2,3]

CCC data show incidence rates that are considerably higher than those of the RGS data (Figure 4). There are several possible explanations for this, including the shortcomings of retrospective surveys. However, it may simply be that diving expeditions are associated with higher rates of morbidity because of constant immersion in warm, tropical water. In the CCC data, the incidence of ear presentations alone is greater than that for all presentations in the RGS studies. Figure 4 shows the incidence rates per 1,000 EPD for these CCC data and those for RGS-registered expeditions between 1995 and 2000.[2,3]

A comparison can be made to other events in which young people commonly participate. A medical incident rate of 10 per 1,000 per day has been reported at a scout camp, 17 per 1,000 at a rock festival and 28 per 1,000 running a marathon.[26] In this context, the relative risk of medical misadventure on diving expeditions, at 20.4 encounters per 1,000 EPD is not excessive.

Figure 4
Incidence per 1,000 expedition-person-days by medical category forCoral Cay Conservation expeditions compared with those of the Royal Geographical Society (RGS)



This paper has a number of limitations. Shortcomings in data and methodology could lead to underestimation of incident rates by up to 20%. The experience and reporting thresholds varied considerably between doctors. Data may well under-represent minor medical problems and misdiagnose diving-related illnesses. However, the CCC data do provide a broad overview of likely illness patterns that will occur during a remote tropical diving expedition.

The present study has several factors in its favour when compared with other published data. While reviewed retrospectively, the data on medical incidents were collected and submitted by medically qualified personnel at or near the time of occurrence. Most other studies, including those of the Royal Geographical Society, used a retrospective survey completed by the expedition leader up to 12 months after the expedition date. In addition, response rates were generally poor (around 30%), whereas CCC data were available for 82.6% of all possible reporting weeks and have provided a large database.

A literature search was unable to identify other studies that were specific to diving or the coastal environment. Figures for these activities were infrequently included in papers reporting on expeditions of all types.[2,3] Many of the studies identified death rates for various activities, rather than the less serious medical incidents.[9,10,16,19,27] Only three studies documented medical cases at the time of occurrence.[4–6] No information on EPD was provided and the definition of an incident – an illness or injury that requires more than simple first aid – prevented any direct comparison with the present study.

In many studies of expedition health, gastroenteritis is the most commonly encountered condition, varying from 26 to 36 per cent of total incidents.[4–6,18,22] This is not the case in the CCC data, where gut conditions contributed only 11% to the total; however, the rate of 2.72 per 1,000 EPD is consistent with RGS figures and those reported by Johnson on walking tours (1.99) and expeditions (3.28).[19] Respiratory symptoms in most studies range from 11 to 21 per cent.[4–6,18,23,28] In the CCC data respiratory tract infections accounted for 11.7% of all presentations. Many studies show that orthopaedic conditions and traumatic injuries play a much greater role than seen here. Injury rates range from 13 to 50 per cent and vary greatly depending on the inherent risk of expedition activities.[2–4,16,20,21,25,28,29]

Animal encounters in RGS papers accounted for 8% of presentations, similar to the 7% seen in CCC data.[2,3] Insect bites and stings dominated in both studies, although sea urchin spine injuries were also troublesome. Foot problems made up a similar percentage of the total. Presentations of this type should be avoidable if participants adhered to basic preventative measures, such as wearing shoes and long, loose garments, and using insect repellents and mosquito nets. Surgical and dental presentations are consistently low across all studies reviewed.

Much has been published on the incidence of decompression illness across various demographics of diving populations.[30,31] In the CCC data, the estimated incidence cannot be known accurately as only one possible case was treated. In most reports, the denominator remains in question. Incidence rates of DCI quoted per 1,000 dives vary from 0.04 for scientific divers to 0.25–0.49 serious incidents for wreck divers in cold waters.[32,33] The rate of DCI in recreationally trained divers undertaking scientific surveys for CCC according to strict diving standards would appear to be close to that of employed scientific divers. CCC has been criticised in the past for having such strict and conservative diving practices. These figures, however, would seem to justify both their existence and their continued use, particularly given the remoteness of project sites from hyperbaric treatment facilities. Only five notable scuba incidents occurred during the study period. The single case of decompression illness would qualify as mild by the consensus definition published in workshop proceedings on management of mild or marginal decompression illness in remote locations.[34]

The diving expedition medical officer needs some knowledge of the treatment of diving injuries; however, medical conditions resulting from the marine environment were far more common. Some of the skin conditions may have originated on land, but were consistently worsened or failed to heal unless the participant abstained from diving and swimming. The single dominating feature of this study was ear conditions, which accounted for 34.5% of all presentations. Edmonds notes that *"although otitis externa occurs without indulging in aquatic activities, swimming increases the risk three to five fold"*, and *"in divers, external ear infection is one of the most common and troublesome disorders encountered"*.[35] Taylor claims it is to be expected that aural barotrauma would be the most common cause of diving injury and this is so in the CCC data.[13] Doctors who deploy to a marine setting should be well equipped to diagnose, treat and implement preventative strategies for infective and pressure-related ear complaints. Antibiotics for treating ear infections, and equipment for performing ear examinations and toilets are essential.

However, common things occur commonly and all expedition medics should be prepared to deal with respiratory tract infections, gastroenteritis, minor trauma and foot injuries. They should carry a good supply of oral and topical antibiotics, rehydration solutions, decongestants, analgesics, minor procedure instruments, wound dressings and skin creams. Time off diving will be recommended for most presentations.

If suitable locality- and activity-specific precautions are taken and travel medicine advice sought well in advance of departure, life-threatening medical conditions, mosquito-borne infections, heat exhaustion, major trauma and decompression illness should be rare. However, due to the serious nature of these conditions and the remoteness of the setting, consideration needs to be given to providing oxygen and resuscitation equipment despite the logistical challenges involved. It would seem prudent to plan routes of evacuation for all weather conditions and assess the standard of care in local hospitals and recompression facilities. This study highlights the importance of good pre-expedition planning and the need for further research on medical presentations encountered on remote diving expeditions.

Conclusions

The presenting complaints commonly seen on a remote tropical diving expedition include ear infections, gastroenteritis, respiratory tract infections, skin conditions, barotraumas and minor soft-tissue injuries. Medical encounters are consistent with those predicted by the findings of terrestrial expeditions, with the addition of conditions attributable to the aquatic setting. The marine environment plays a dominant role in aetiology and is arguably responsible for half of all cases. The relative risk of joining a remote tropical diving expedition is low and comparable to leisure activities in which young people commonly participate. Doctors deployed to a remote diving expedition should carry good supplies of oral and topical antibiotics, ear drops, nasal decongestants, rehydration solutions, topical creams, analgesics and wound-dressing kits. They should also give serious consideration to providing oxygen and resuscitation equipment.

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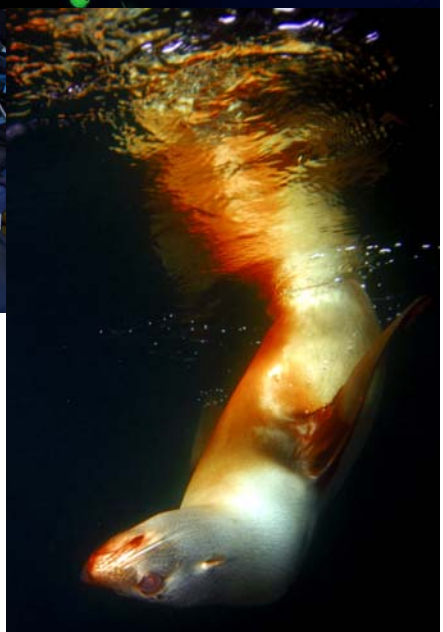


Technical diving? No sweat!

Mike Davis and Sarah Webb
wish all readers
a Happy Christmas
and
a healthy and
successful 2008





Ventilator performance under hyperbaric conditions: a study of the Servo 900C ventilator

Gordon Bingham, Bill Koch, Geraldine Lee and Ian Millar

Key words
Ventilators, equipment, hyperbaric oxygen, hyperbaric research

Abstract

(Bingham G, Koch B, Lee G, Millar I. Ventilator performance under hyperbaric conditions: a study of the Servo 900C ventilator. *Diving and Hyperbaric Medicine*. 2007; 37: 199-203.)

When critically ill individuals receive hyperbaric oxygen therapy (HBOT), adequate and reliable ventilation is of great importance. The Servo 900C ventilator is widely used in this setting but its performance at pressure has been incompletely characterised.

Aims of the study:

1 To establish if the Servo 900C ventilator exhibits a reduction in delivered minute volume (MV) when used in synchronised intermittent mandatory ventilation (SIMV) mode at the maximum pressure commonly utilised in hyperbaric medicine practice.

2 If so, to calculate the correction factor(s) that needs to be applied to the ventilator settings in order to maintain delivery of the desired MV whilst at 283 kPa.

Methods: Ventilation using the Servo 900C ventilator was simulated with a test lung at sea-level atmospheric pressure (101.3 kPa) and at a pressure of 283 kPa in a hyperbaric chamber. The ventilator was operated in synchronised intermittent mandatory ventilation (SIMV) mode. Gases were collected from the exhaust valve of the ventilator to measure minute volume during simulations.

Results: Significant differences exist between the MV delivered at 101.3 kPa and that delivered at 283 kPa, for ventilator MV settings of 1.0, 10 and 15 L.min^{-1}. It is possible to fully compensate for the reduction in delivered MV at a desired setting of 1 L.min^{-1} but full compensation cannot be achieved for set MVs of 10 and 15 L.min^{-1}.

Conclusions: When using the Servo 900C ventilator in SIMV mode in a hyperbaric chamber at 283 kPa, it is possible to achieve delivery of desired MV at the lower settings. However, it is not possible to deliver MVs of 10 L.min^{-1} or more at this pressure. This has implications for the ventilation of adult patients who concurrently require HBOT.

Introduction

Critically ill patients who receive hyperbaric oxygen therapy (HBOT) may in some circumstances need concurrent mechanical ventilation. Variations in ventilator performance due to changes in ambient pressures associated with HBOT may have the potential for life-threatening consequences if not detected and corrected.[1,2]

As technology has progressed, ventilators with more complex ventilation strategies are being used within hyperbaric chambers. The ventilators used are typically designed to operate at atmospheric pressures between sea level and moderate altitude only. When such ventilators are used in a hyperbaric chamber at raised atmospheric pressure there may be differences between *set* ventilation parameters and what is *actually* delivered to the patient.[3]

The aim of this study was to establish if, at raised atmospheric pressure, a Seimens Servo 900C® (Seimens, Elena AB, Solna, Sweden) ventilator exhibited significant reductions in delivered versus set minute volume (MV). Further it aimed to establish the correction necessary to maintain the desired volumetrically constant MV at a chamber pressure of 283 kPa across a range of minute volumes representative of the requirements of clinical practice.

The hyperbaric performance of the Servo 900C in volume preset mode has been previously reported. When using synchronised intermittent mandatory ventilation (SIMV) mode, this ventilator operates using a flow servo loop, which functions by measuring actual gas flow from the inspiratory flow transducer (a screen-type pneumotachometer).[4] The ventilator compares this volume with the preset inspiratory MV chosen by the operator. When actual flow does not match the preset inspiratory MV, electronic control opens or closes a 'scissors style' inspiratory flow control valve to provide an adjustment of the gas flow and consequent volume delivery.

A specific failing of the pneumotachometer type of flow sensor is that the output signal of such sensors is sensitive to pressure and, unless there are electronic systems present to compensate for this, gas delivery becomes increasingly inaccurate as the ambient pressure rises.[3,5,6] Our hyperbaric unit regularly uses the Servo 900C ventilator and we therefore undertook further investigations in this area.

Research methods and materials

As an equipment performance study not involving research subjects, there was no requirement for ethics committee approval. The hyperbaric chamber used was a clinical, multiplace, three-compartment unit (Fink Engineering, Melbourne).[7]

The MV delivered by the ventilator was measured at ambient pressure of 101.3 kPa and at 283 kPa. Where delivered MV was less than the set MV, the set MV was increased incrementally to discover what correction value was necessary to compensate for the shortfall. During testing the ventilator was operated with a test lung (Siemens test lung 190®), which was attached to the ventilator's patient circuit to approximate normal physiological resistance.[8]

Delivered MV was measured by timed collection of output from the exhaust valve of the ventilator. Exhaust gas was collected via a low-resistance system (Figure 1) incorporating a three-way, manual, directional control valve for gas diversion (Hans Rudolph, Missouri, USA) and a Douglas collection bag (Vacumed, California, USA). Volume was measured with a two-litre calibration syringe (A-M Systems Inc, Carlsborg, Washington). A vacuum pressure gauge was also incorporated into the bag to facilitate consistent emptying of the collection bag prior to each measurement.

A single Servo 900C ventilator was used for the study (Figure 2). The machine had undergone 277 hours of hyperbaric use since the last service but prior operational hours were unknown. During the course of data collection no servicing was required. Data were collected whilst operating the ventilator in SIMV mode.

RESEARCH PROCEDURES

The ventilator settings chosen for testing purposes were considered typical of starting-point ventilatory parameters and consistent with literature reports.[9,10] These were:

- respiratory rate of 10–20 breaths per minute
- pressure support of 12 cmH_2O
- positive end expiratory pressure (PEEP) of 5 cmH_2O
- 100% oxygen

Figure 2
The Servo 900C ventilator

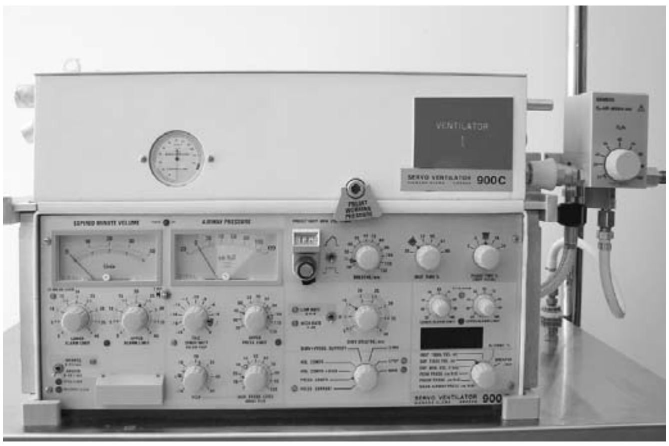
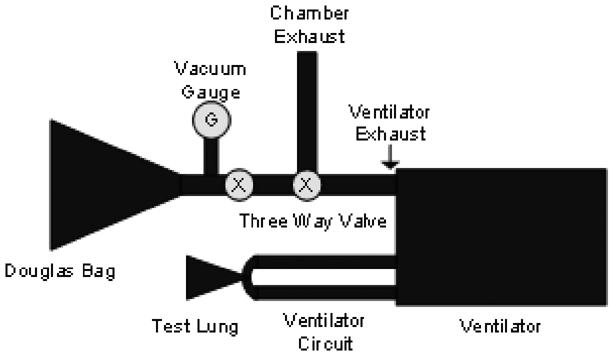


Figure 1
Collection circuit used to measure delivered minute volume



Minute volumes of 1.0, 10 and 15 $L.min^{-1}$ were chosen to span the range of paediatric, normal adult and large catabolic adult volumes.

Prior to data collection the ventilator was set up in accordance with normal practice. Air from the collection bag was evacuated prior to each measurement with the measuring syringe. A vacuum was confirmed to be present on the gauge prior to advancing the syringe to zero pressure. This ensured consistent removal of all air from the collection bag and that there were no leaks in the system.

The ventilator was set to the desired respiratory rate. The Siemens Servo 900C ventilator has a lid which can be opened to allow observation of the 'scissors style' valves that control inspiratory and expiratory flow. The operator timed the actual respiratory rate and made fine adjustments to the ventilator's rate setting as needed to ensure that exactly one minute elapsed from opening of the respiratory scissors valve to the closing of the expiratory valve after the desired number of ventilation cycles.

The procedure for MV collection was to open the three-way valve into the collection bag when the ventilator's expiratory valve closed at the beginning of inspiration. Upon closure of the expiratory valve after the last breath and one minute later the three-way valve was closed to the collection bag. The graduated calibration syringe was then used to evacuate the volume of the collection bag until a negative pressure was recorded on the vacuum gauge. The syringe was then advanced until a zero pressure reading was obtained on the vacuum gauge. The operator then recorded the volume on a data collection sheet.

SAMPLE SIZE

For each ventilator setting, measurement was performed 20 times at sea-level pressure and 20 times at a pressure of 283 kPa. Prior to analysis of the data, an examination of the underlying distribution was undertaken. Two independent operators collected and measured volumes using the same technique to test for the possibility of operator technique error.

Results

All data were analysed using SPSS® v13.0. The examination of data distribution suggested that data for each ventilator setting and pressure condition were approximately normally distributed, and parametric tests were used (Fisher's and Pearson's skewness coefficients were 1.96 and 0.50 respectively).[11–13] Comparisons between set and delivered MV were therefore conducted using independent t-tests.

RELIABILITY OF OPERATOR TECHNIQUE

There was no statistically significant difference in the volumes collected by different operators ($t = -1.14$, df =15.12, $P = 0.27$).

MINUTE VOLUMES DELIVERED

There was a significant reduction in actual delivered MV at 283 kPa for all set MVs (Table 1). At the nominally typical high, but not extreme, adult ventilation MV setting of 10 $l.min^{-1}$, the ventilator actually delivered 9.55 $L.min^{-1}$ at 101.3 kPa and 6.53 $l.min^{-1}$ at 283 kPa (95% CI 2.97–3.00, $P < 0.01$).

CORRECTION VALUES TO COMPENSATE FOR UNDER DELIVERY

In an attempt to identify an appropriate correction factor, the ventilator's set MV was progressively increased with the aim of achieving delivery of the desired MV. An MV setting increase of 0.7 $L.min^{-1}$ was required to achieve a desired MV of 1 $L.min^{-1}$ at 283 kPa. However, for the set MVs of 10 $L.min^{-1}$ and 15 $L.min^{-1}$ the maximum MV achievable at 283 kPa was approximately 9.25 $L.min^{-1}$.

Even adjusting the MV by +25 $L.min^{-1}$ above the set MV of 1 $L.min^{-1}$ (Figure 3) or increasing the set MV to the ventilator maximum of 99.9 $L.min^{-1}$ (Figure 4) did not raise the maximum delivered MV above a plateau short of the desired MV for settings of 10 and 15 $L.min^{-1}$.

Discussion

Although it was designed over 20 years ago, the Servo 900C is a moderately sophisticated ventilator, which has been extensively used in the intensive care setting. It remains one of the most advanced HBOT-compatible ventilators given its multiple modes of ventilation, including continuous

Figure 3
Effect of increases in set minute volume (MV) on delivered MV at 283 kPa
(baseline set MV = 1.0 $L.min^{-1}$)

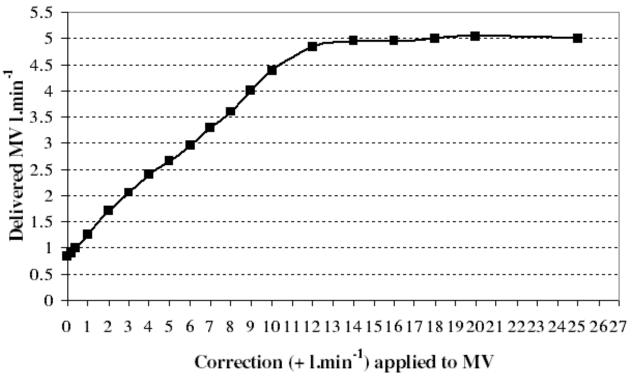


Figure 4
Effect of increases in set minute volume (MV) on delivered MV at 283 kPa
(baseline set MV = 10 $L.min^{-1}$)

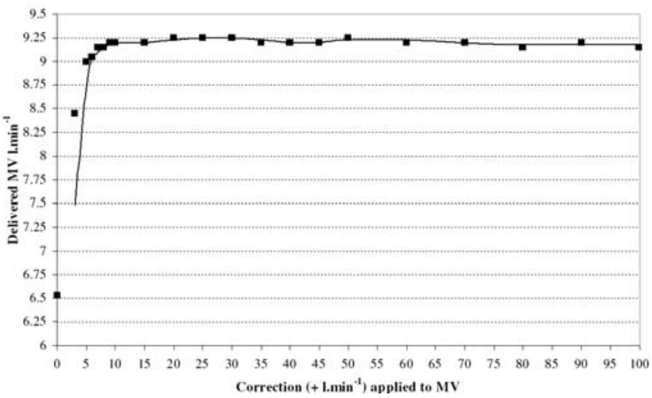


Table 1
Delivered minute volume at 101.3 kPa and 283 kPa relative to set minute volume (MV)

Pressure (kPa)	Number of readings	Set MV ($L.min^{-1}$)	Mean delivered MV ($L.min^{-1}$)	Standard deviation	P value	95% CI
103	20	1	1.03	0.025	< 0.01	0.17–0.20
283	20	1	0.84	0.022	< 0.01	0.17–0.20
103	20	10	9.55	0.040	< 0.01	2.97–3.00
283	20	10	6.53	0.070	< 0.01	2.97–3.00
103	20	15	14.5	0.050	< 0.01	5.34–5.43
283	20	15	9.12	0.070	< 0.01	5.34–5.43

mandatory ventilation (CMV), synchronised intermittent mandatory ventilation (SIMV), pressure control ventilation (PCV), continuous positive airway pressure (CPAP) and pressure support (PS).[14,15]

Literature on the use of this ventilator within hyperbaric settings remains sparse. Some studies have demonstrated that raised ambient pressure in a hyperbaric chamber may cause disparity between displayed and delivered tidal volume (TV) and MV, with a reduction in the volumes actually delivered compared with those set.[3,5,15]

A recent study involving a range of ventilators including the Servo 900C is one of the more scientifically rigorous to date, with the measurement apparatus detailed and methodology clearly outlined.[3] In this study each ventilator was tested at 101.3, 131, 161, 192, 283 and 608 kPa. The ventilator settings for testing were reported to be a TV of 750 ml, an inspiration/expiration (I:E) ratio of 1:2, and respiratory rates of 10, 15 and 20 breaths per minute. These settings were tested in both SIMV and (if available) PCV modes.

The study results noted a decrease of TV in SIMV mode as ambient pressure rose, a change attributed to the increasing gas density at raised ambient pressure. The MV and TV shown by the ventilator's digital displays were higher than the actual delivered volumes, consistent with our observations from clinical practice. In order to compensate for this, the authors reported increasing the delivered volumes to achieve the preset values but no correction values were cited. The conclusion was that although alteration of function occurs this could be accommodated and constant ventilation achieved, although at higher atmospheric pressures compensation was limited due to the range of the ventilator.

These results were consistent with a previous study on the Servo series of ventilators, which reported one set of data in the hyperbaric environment.[5] In this study the ventilator was set to deliver 10 $L.min^{-1}$ at 101.3 kPa and actually delivered only 6 $L.min^{-1}$ at 283 kPa. It also reported that the ventilator's digital displays of delivered MV read artificially high values at pressure as a consequence of the pneumotachometer flow sensor. The investigators claimed to have increased MVs to achieve the original settings and reported operation of this ventilator for hundreds of hours without malfunction, but no information was provided with respect to the correction factors necessary or the maximum volumes able to be delivered.

The results of our study are consistent with previous findings, showing significant differences between the delivery of MV at ambient pressure and at 283 kPa for set MVs of 1.0, 10 and 15 $L.min^{-1}$.[3,5,15] The reduction in MV delivered at 283 kPa was clinically significant – enough to require correction to achieve results closer to the desired MV. The particular maximum output we identified (approximately 9.5 $L.min^{-1}$) is probably specific to the rate, pressure support, PEEP and I:E ratio settings we chose for the study. However, it is clear that the ventilator has output limitations at pressure in the SIMV mode that can be clinically important. Such deviations of delivered MV from the set MV may represent a threat to the patient through hypoxia and/or hypercarbia.

As mentioned in the introduction, a specific failing of the pneumotachometer type of flow sensor is that the output signal of such sensors is sensitive to pressure and, unless there are electronic systems present to compensate for this, gas delivery becomes increasingly inaccurate as the ambient pressure rises.[3,5,6]

Whilst it is possible to fully compensate for the reduction in delivered MV at 283 kPa when a set MV of 1 $L.min^{-1}$ is desired, and near compensate for a MV of 10 $L.min^{-1}$, the latter setting appears to represent an output plateau for this ventilator at this pressure. This may be clinically relevant in the case of large patients or those with respiratory or catabolic (e.g., septic) complications and/or injury.[16] Strategies to slightly raise delivered MV in this mode may include an increase in respiratory rate, and lengthening of the inspiratory period, although the latter carries a theoretically increased risk of gas trapping and barotrauma on chamber depressurisation. Reducing pressure support or PEEP is unlikely to be desirable in a patient requiring large MV ventilation.

Some investigators have suggested that MV delivery in the Servo 900C ventilator is less affected at raised atmospheric pressure when in PCV mode rather than the volume-control mode of SIMV,[3] and it is our clinical practice to change to PCV if ventilation in SIMV mode proves inadequate.

It may be that use of PCV mode should be encouraged during HBOT. However, patient–ventilator synchrony and patient comfort are usually better if one does not change ventilation mode in the case of minimally sedated patients being ventilated in SIMV mode in the intensive care unit. Other problems that can be associated with the PCV mode include higher peak inspiratory pressures, which may be associated with pulmonary barotrauma, plus an increase in mean airway pressure, which can lead to an increase in right ventricular afterload, decreased cardiac preload and reduced cardiac output requiring inotropic support and/or fluid volume loading.[17]

Conclusions

It is possible to utilise the Servo 900C ventilator in SIMV mode in hyperbaric chambers by increasing the set MV with pressurisation in order to maintain delivery of the desired MV. However, the ventilator has a maximum output that may limit its usability in this mode of ventilation. The ventilator's displays of delivered volumes will be above the actual delivered volumes, which should therefore be measured with an independent, pressure-calibrated volumeter or flowmeter. At 283 kPa the ventilator tested demonstrated a maximum deliverable MV of approximately 9.5 L.min^{-1} with pressure support of 12 cmH_2O and PEEP of 5 cmH_2O.

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International Life Saving World Drowning Report 2007

The International Life Saving Federation (ILF) World Drowning Report was presented at the World Water Safety Conference in Portugal recently. The following are excerpts from that report.

The World Health Organisation (WHO) noted that drowning is the third leading cause of unintentional death globally after road traffic injuries and falls (World Health Report 2004)

New Zealand has the third highest drowning toll at 3.3 per 100,000 population in the world, behind Brazil (3.5) and Finland (3.4). Australia is sixth highest (1.5).

ILS data identified key groups or locations most susceptible to drowning:

- Children under five years (and adults, 18–49 years)
- Gender (male)
- Place of occurrence (rivers, lakes, oceans and creeks)
- Climate conditions (low temperature)
- Safety equipment (no lifejacket)
- Use of alcohol (for men when boating and swimming)
- Parental supervision (lack thereof for young children)

Most reports on drowning injury note the difficulties and unreliability of data collection in developing countries.

New Zealand was again noted for the accuracy of its drowning data along with the ease with which they are collected.

The ability to develop drowning prevention initiatives from reliable evidence is critical to reducing the incidence of drowning over time, something that has unquestionably occurred in New Zealand since 1980 from when detailed fatal drowning data have been recorded.

Review article

Scientific diving in Antarctica: history and current practice

Neal W Pollock

Key words
Antarctica, diving, scientific diving, hypothermia (see thermal problems), equipment, logistics, safety, review article

Abstract
(Pollock NW. Scientific diving in Antarctica: history and current practice. *Diving and Hyperbaric Medicine*. 2007; 37: 204-11.)
Diving has served as an important research tool in Antarctic science for the past 50 years. Equipment, techniques and oversight have developed to make it a mainstream function in many polar programmes. The safety record is encouraging, particularly given the unforgiving nature of the environment.

Introduction

Diving has long been an important tool in underwater science. This is true even under the extreme conditions of the Antarctic. The first recorded event was a surface-supplied dive conducted in April 1902 during a 1901–03 German expedition.[1] The US Underwater Demolition Team (UDT) tested their cold-water wetsuits at the surface and completed at least one dive in the Antarctic in February 1947 during Operation Highjump.[1–3] The first Australian dive was conducted by Phillip Law in March 1956 at Mawson Station (67^{O}62'S 62^{O}87'E).[4] Antarctic peninsular research diving was reported by Americans participating in an Argentinean cruise in 1958 (exploring as far south as Paradise Harbour, 64^{O}51'S 62^{O}54'W);[5,6] the British in 1962 (Signy Station, 60^{O}43'S 45^{O}36'W);[7,8] the French in 1962 (Morbihan Gulf, 49^{O}25'S 70^{O}8'E);[9] the Russians in 1965 and 1968;[10,11] the Japanese in 1968 (Syowa Station, 69^{O}00'S 39^{O}35'E);[12,13] and New Zealanders in 1970.[14]

Protective suits

Protective suits were the first priority. Early practice employed a range of equipment, some as used in more temperate waters and some modified for polar conditions. Both wetsuits and drysuits were used in early dives. The reality of wetsuits was most graphically captured by Norton: "*Endurance increased as diving suits improved, notably the introduction of the zipperless two or three piece suit of unlined 10 mm neoprene. However, dressing consumed half the world's talc production and undressing was like skinning a reluctant rabbit.*"[7]

The potential for the greater thermal protection with drysuits was acknowledged in early cold-water trials.[15] Drysuits of this era, however, were very different to modern suits. Without valves, the internal airspace was compressed with increasing depth ('suit squeeze'), reducing the thermal protection, producing large changes in buoyancy, and often increasing the likelihood of leakage. These concerns, and those of added bulk and restricted mobility, led many early dive teams to prefer wetsuits.[5,6] Others wore wetsuits under drysuits to maximize in-water times.[16]

The modern polar diver is unlikely to use a wetsuit for any operation or as an undergarment. Suit and undergarment technology have evolved to bring the –1.9^{O}C water temperature found along the continental Antarctic to within a reasonable tolerance range. A variety of configurations are available to provide levels of (relative) comfort (see Figure 9, photospread). The most sensitive issue for diver performance is hand temperature. Unfortunately, dexterity and thermal comfort are competing priorities. Practically, the choice will vary with the length of the intended dive and task requirements.

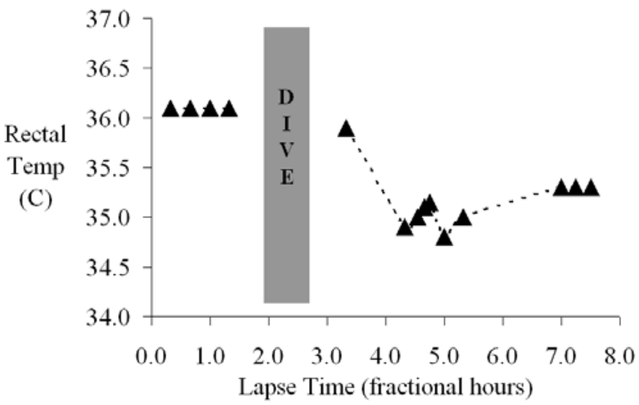
Thermal stress

The challenges for thermal protection in polar diving are the high thermal capacity (i.e., the product of specific heat and thermal conductivity) of water and practical limits to the bulk of thermal-protection equipment that can be worn whilst maintaining adequate mobility. The demands on protective suits can be put in perspective by considering the influence of cold-water immersion on unprotected persons. A research group in Canada immersed 21 lightly clothed subjects to the lower neck in water of 0^{O}C stirred at 0.2 $m.s^{-1}$. The subjects remained in the water on average for just over 30 minutes. The core temperature in these unprotected subjects fell at a rate of –6.4 ± 0.7^{O}C for males and –5.6 ± 0.7^{O}C for females. The ability to self-rescue was lost in a matter of minutes.[17] The cold-water diver faces the additional challenge of having the head fully immersed, a major centre of heat loss.

Limited data exist on the core temperature response of polar divers, but those available suggest it has a fairly modest impact.[18–20] The 35^{O}C threshold for hypothermia is likely rarely reached. The response of a diver to an unusually extreme polar dive (19 November 1993) is offered as an example. The diver donned a drysuit ensemble (full cover polypropylene underwear, fleece jumpsuit, heavy-weight Thinsulate™ jumpsuit and a Diving Unlimited International CF200 crushed neoprene drysuit) in a heated hut and then travelled approximately eight kilometres by snow machine in less than 20 minutes to reach an uncovered dive hole (78°S latitude). The air temperature at the site was –6°C with variable wind around 8 km.h^{-1}. Upon entering the water the diver realised that there was a leak near the bottom of the front entry zipper, allowing water to enter the suit (noticeable immediately upon immersion). The diver opted to continue the dive to survey the underside of an iceberg. The team proceeded to a depth of 36 metres' sea water (msw) to begin the survey, then moved progressively shallower. The seawater temperature was a uniform −1.9°C. Water continued to infiltrate the suit, soaking the undergarments up to the top of the chest anteriorly and the upper lumbar region posteriorly. The diver chose to abort the dive when he realised that he was having difficulty mentally computing manual camera settings. The total underwater time was 43 minutes. The diver then drove the snow machine back to the heated hut to change.

Coincidentally, the diver had a rectal probe in place to track his core temperature over the course of the day. Readings were taken until the drysuit was sealed prior to travel to the outside hole and immediately upon opening the suit after return to the building two hours later (Figure 1; Pollock N, unpublished data). The diver had a stable pre-dive rectal temperature of 36.1°C. A temperature of 35.8°C was measured when the suit was first opened in the hut post-dive. Measured rectal temperature fell after the diver changed clothing, to a low of 34.8°C, only recovering to 35.3°C within the next two-and-one-half hours while the diver remained in a heated building. This example highlights the limitations of rectal temperature in reflecting whole-body thermal stress. It can be insensitive to thermal cooling that may ultimately be important. In this case, removing the suit and undergarments and drying/warming the skin likely combined a rapid attenuation of shivering thermogenesis, increased convective cooling via changes in peripheral blood flow, and possibly increased conductive heat loss along tissue thermal gradients.[21,22] The impact of these events, primarily through heat redistribution within the body, was evident as rectal temperature 'afterdrop' only long after the end of the exposure period.

Figure 1
Extreme core temperature response to a 43-minute outside dive (with drysuit leak) in –1.9°C seawater; maximum depth 36 msw; air temp –6°C; wind at 8 km.h^{-1}



While secondary to immersion stress, there are also physiological considerations of hyperbaric exposure on thermal stress. Respiratory heat loss increases under hyperbaric conditions as gas density and heat capacity increase. Generally this becomes a significant avenue for heat loss only at depths greater than 200 m, particularly when breathing helium-oxygen gas mixtures,[23,24] but the combination of cold polar water and the cooling of expanding gas is not trivial. A field study of regulator performance reported mean first stage housing temperatures of –3.8±0.6°C during typical Antarctic dives.[25] The actual gas temperature was likely lower than this as the housing temperature (measured within a partial thickness hole drilled in from the outside) was simultaneously being warmed by the surrounding water.

Finally, there is also some evidence for a narcosis-induced reduction of heat production during cold-water immersion.[26–28] Further work is required to determine what practical influence this may have on the polar diver. Both respiratory heat loss and narcosis-related impairment will become more important if operational depth increases as it has for scientific diving in more temperate regions.

Breathing apparatus

While surface-supplied and closed-circuit devices were used in the earliest operations,[1,4,6] open-circuit scuba diving with double-hose regulators became the predominant choice for Antarctic diving beyond the late 1950s.[12,16,29,30] The advent of single-hose regulators prompted a series of comparison trials under polar field conditions.[31] The double-hose regulators were substantially more reliable for cold-water use than any single-hose regulator at that time and were confirmed as the standard for polar operations. While single-hose regulators evolved, a largely unchanged style of double-hose regulator served the polar diving community for almost two decades. Eventually, the reliability of these units suffered, largely due to an increasingly limited supply of parts. The failure rate observed in the US Antarctic programme reached a peak in 1990, when individual regulators had a failure rate as high as 40%.[32] Regulator failure is usually expressed as a progressive free flow instead of an abrupt loss of air supply. Breathing can become difficult and gas loss severe, but the diver should have a redundant regulator to switch to while swimming toward an escape hole. The possibility of failure kept dives short, since the risk increased over time for some regulators, and close to a point of egress. A study of regulator performance started in 1989 indicated superior reliability of several single-hose regulators,[33] including Poseidon models already adopted by the British and New Zealand programmes.

Continued testing within the US programme led to the selection of the Sherwood Maximus™ as the new standard because of its combination of reliability and ease of servicing. The model demonstrated a 1.7% failure rate in 1,341 dives conducted over a four-year period, an order of magnitude lower than the 17.4% failure rate of the double-hose US Divers Royal Aquamaster™ in its final two years of service.[25,34]

Of historical interest is the fact that unmanned testing conducted by the US Navy concluded that the Sherwood Maximus™ could not be recommended for cold-water use.[35] Some confusion arose in that the Maximus regulators tested by the Navy did not include a heat retention plate provided by the manufacturer in some of the regulators field tested in the US Antarctic programme.[25,36] The heat retention plate was associated with a non-significant reduction in the failure rate observed with polar use.[25] The Sherwood Maximus™, with heat retention plate, remains the standard regulator for the US Antarctic programme, with a cumulative failure rate of 0.3%.[37] This experience reinforces the importance of field testing in addition to bench trials. Cautious field testing is even more important before accepting performance claims of new devices with no independent testing history. Memory of the performance of the Royal Aquamaster™ regulator in its final years should also drive additional effort to test new regulators to find a replacement for the Sherwood Maximus™ before similar ageing problems occur.

Polar diving programmes

While many countries likely conduct at least some diving in conjunction with Antarctic research programmes, the literature record is highly variable.

UNITED STATES

The United States maintains the greatest physical presence in the Antarctic. The largest Antarctic facility is McMurdo Station on Ross Island (77°51'S 166°40'E), established in 1957 and now supporting in excess of 1,000 persons in summer and around 250 persons in winter. Formalised diving procedures were established at McMurdo sometime prior to 1960.[30] The first reported under-ice dive was made in November 1961, with a total of 35 dives completed over the following year.[16] Ten more under-ice dives conducted in 1963 were reviewed by Ray and Lavallee.[29] Given the dominance of fast ice in the vicinity of McMurdo Station, the majority of dives were under-ice once the ability to conduct these operations was established. The ice thickness at the entry point can range from 1.5–5.8 m.

Formal records of US Antarctic programme diving activity between 1960 and 1978 were not preserved. The only available means to estimate McMurdo diving activity between 1978 and the 1988/89 season is the service log of cylinder fills maintained with the main station air compressor.[38] Totals from 1978/79 to 1993/94 are listed in Table 1 (Mastro JG, personal communication, 1994). These totals undoubtedly underestimate total dives, particularly those conducted during the non-winter periods, since they do not include fills made with a portable compressor available for remote field operations. The difference between fill records and dive log totals for the 1989/90 and 1990/91 seasons provides an indication of the potential magnitude of this problem. The addition of a cascade storage system to the McMurdo air station in 1990 (allowing cylinders to be filled without starting the compressor) might have further confounded the picture but, fortunately, dive records were captured by that time.

Table 1
Air compressor records from McMurdo Station

Season	Compressor fill record total	Logged dive total
1978/79	106	
1979/80	51	
1980/81	177	
Winter 1981	162	
1981/82	347	
Winter 1982	110	
1982/83	157	
1983/84	143	
1984/85	908	
Winter 1985	106	
1985/86	252	
Winter 1986	29	
1986/87	83	
1987/88	132	
1988/89	226	
1989/90	394	526
1990/91	481	658
1991/92	313	288
1992/93	444	435

Bearing in mind the shortcomings, a total of 2,989 fills were recorded between the 1978/79 and 1988/89 seasons. Annual fill totals ranged from 51 to 908. (Note: winter fills were arbitrarily added to the following summer season for these calculations). The median number of fills recorded annually was 177 (mean ± standard deviation 272 ± 248).[38]

Centralised record-keeping of diving activity within the US Antarctic programme was initiated in the 1989/90 field season. A total of 3,113 person-dives were completed between 1989/90 and 1994/95; 519 ± 183 (288–795) annually. Underwater time varied dramatically, up to 76 minutes.[38] The annual number of dives was more stable from 1996 through 2006, averaging around 800 and peaking in

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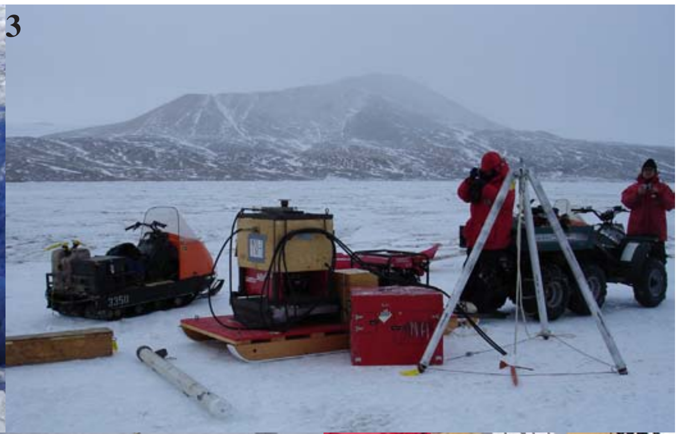

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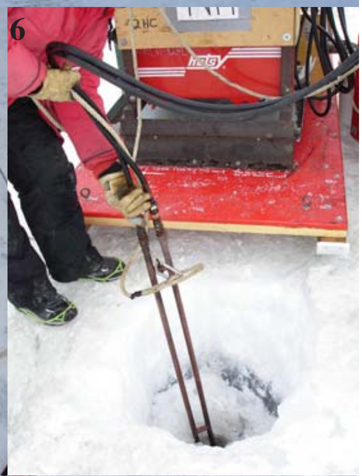

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Figure 2. Cape Bernacchi dive hole
Figure 3. Hole melter assembly beginning hole melting process
Figure 4. Hydraulic drill assembly (1.2 m diameter drill) towed in vicinity of McMurdo Station
Figure 5. Hole melter partially inserted into ice
Figure 6. In-hole heating trombone used to start the melting
Figure 7. Keeping warm whilst hole melting
Figure 8. *Leptonychotes weddellii* hauling out of dive hole
Figure 9. Diver beside an ice wall

2002 at 1,200.[37] A total of 10,859 dives were logged in the programme from 1989 through 2006. The average dive had a depth of 22 msw and a duration of 34 minutes.[39]

The 1994/95 season was the first from which reliable records of diving activity are available for the US peninsular Palmer Station on Anvers Island (64°46'S 64°05'W). A total of 79 dives were completed by 11 divers. The mean underwater time was 23 minutes and the mean number of dives was 7.2 per diver per season (Mastro JG, personal communication, 1996). A practical description of pack-ice diving practices employed in the peninsula was recently reported.[40] All diving activity in the US Antarctic programme is currently managed and monitored under a health and safety initiative administered by the National Science Foundation.[37]

UNITED KINGDOM

The British Antarctic Survey (BAS) has maintained a record of its diving activity since 1962. A brief review was published in 1995.[8] The total number of dives conducted per year exceeded 100 in 1969, 200 in 1972, 300 in 1984, and 600 in 1993. Approximately two-thirds of these were open-water dives. The number of under-ice dives peaked at more than 200 in 1987. A total of 1,254 dives were conducted at the peninsular Signy Station, South Orkney Islands, in 1993 and 1994. Almost 87% were open-water dives. The mean dive duration was just over 18 minutes, with a maximum underwater time of 78 minutes. The mean depth was 12.7 msw, with a maximum depth of 45 msw.[8] Another 112 dives conducted from an oceanographic vessel were also described.[41] The majority of BAS diving is now conducted at the peninsular Rothera Station on Adelaide Island (67°34'S 68°08'W). The range of work conducted was recently reviewed.[42] A total of 5,492 dives were logged in the BAS programme from 1989 through 2006.[39]

AUSTRALIA

Diving in the Australian programme was primarily limited to the austral summer prior to 1982. A year-round programme was initiated in 1982 at the continental Davis Station (68°35'S 77°58'E).[19] No data are available on dive tallies. A summer diving programme was established at the continental Casey Station (66°16'S 110°31'E) in 1999. Both scuba and surface-supply modes were supported. A total of 1,099 dives conducted over a five-year period were reviewed in 2004. The mean underwater time was reported to be 40 minutes with 92% of the dives shallower than 20 msw (Watzl RF, personal communication, 2005).

NEW ZEALAND

Diving from Scott Base (77°38'S 166°24'E), 3 km from McMurdo Station, began in 1985.[43] The ongoing activity is modest, varying from year to year, often taking advantage of holes prepared for dive teams in the US programme. A total of 1,296 dives were logged in the New Zealand (NZ) programme from 1985 through 2006.[39,43]

Procedures

Antarctic research diving is almost universally restricted to no-decompression diving, although the allowable decompression models vary. The British, NZ and Australian programmes require adherence to the Canadian DCIEM dive tables while the US programme requires the US Navy tables or an ‘approved’ dive computer. The majority of programmes require tended line tethers for all under-ice diving. The exception is the US programme, which employs tended lines under some conditions (low visibility, current, etc.) but generally allows free-swimming operations with holes marked by downlines festooned with flags, multiple compact strobe lights and a 400 L bail-out bottle with regulator. Dive depth is limited to 30 msw within the Australian, NZ, and Norwegian programmes. The US programme maintains a 40 msw limit with approval possible for deeper dives if required. Maximum dive duration is 40 minutes for the NZ programme, 60 minutes for the Australian programme, and not specified in the US programme.

Dive hole construction

Pack-ice diving common in the Antarctic peninsula may include access into fairly open water from small boats or from holes cut into stable pack-ice floes.[40] Access in the fast-ice environment of the continental Antarctic may be through tide cracks or through holes opened in the solid ice. Tide cracks may be wide enough to allow free access but may also be prone to sudden changes in conformation. Fast-ice holes are typically preferred, frequently covered by surface shelters for protection from ambient weather conditions. Ice holes can be opened by progressively cutting/drilling and removing manageable sections of ice from the surface to create a hole of the desired size. The holes flood when the full thickness of the ice is finally breached, typically filling to within 25 cm of the ice surface (Figure 2). This approach is time intensive, described by an early dive team as requiring 32 man-hours to clear a 2.3 m wide hole through 4 m thick ice.[29] A hydraulic drill (Figure 4), currently capable of opening 1.3 m diameter holes in a few minutes has replaced manual labour in the vicinity of McMurdo Station.[37,44]

Sealed glycol melters offer an option for opening holes at remote sites,[45] but still with significant effort (Figures 3 and 5–7). Transporting the necessary equipment is no mean feat in areas with rough surface ice, particularly when multiple holes are required. The melting process is also time-consuming. The equipment must be closely monitored to ensure that the melting is progressing in a useful direction. Sideways slippage of the heat transfer assembly may stop progress if the resultant pool is large enough to absorb sufficient heat energy. Too rapid a vertical advancement may place enough of the assembly under the lower reach of the ice to similarly stop widening progress. The maximum vertical penetration is also dependent on the length of the hose and heat transfer assembly. Additional length increases the volume of glycol required and the collateral heat loss in the early stage of operation, when the supply lines remain in the air. Melting a dive hole through 5.0–5.8 m of ice can take between 24 and 36 hours.

Explosives remain a necessary option in some locations.[37,44] They allow the construction of holes of almost any practical size through 6 m or more of ice with six to eight man-hours of labour, primarily spent moving pulverized ice and checking for clear passage between blasts.

Diving safety

Hyperbaric chambers are available at McMurdo (US), Rothera (UK) and Casey (Australia) stations. Diving anywhere outside the immediate vicinity of a hyperbaric chamber may result in significant delay to treatment since surface transport options are typically limited and air travel is restricted to visual meteorological conditions. A pilot effort to test a 2.6 hour in-water recompression protocol confirmed that thermal stress issues rendered the option untenable.[46,47] Dive groups will typically carry emergency oxygen, frequently for open-circuit delivery but in some cases with closed-circuit devices, which can dramatically extend supply time.[43,48] Fortunately, despite potentially-augmented risk factors of cold stress, obligatory physical labour, and prevailing low atmospheric pressure, decompression sickness is a fairly rare event in Antarctic research diving. A recent report describes incident rates of 0, 0.18 and 0.55 cases per 1,000 person-dives for the New Zealand, US, and BAS programmes, respectively. This represents an overall rate of 0.28, or five cases in 17,647 dives. There were no reported cases of arterial gas embolism.[39]

Two fatalities related to scientific diving in the Antarctic have been documented. A male research diver in the US programme died in November 1987 when buoyancy problems developed during an effort to transport a piece of experimental apparatus weighing approximately 18 kg from the surface to the bottom under fast ice in a field camp at Explorers Cove, New Harbor (77°34'S 16°35'E), 80 km west of McMurdo.[49,50] A female researcher in the British programme died in July 2003 following an unprovoked attack by a leopard seal (*Hydrurga leptonyx*) while she was snorkelling with a partner on a research site adjacent to Rothera Station.[51]

Conclusions

Diving has served as an important research tool in Antarctic science for the past 50 years. Equipment, techniques and oversight have developed to make it a mainstream function in many polar programmes. The safety record is encouraging, particularly given the unforgiving nature of the environment.

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Dr Pollock was the Guest Speaker at the 2007 SPUMS Annual Scientific Meeting at Tutukaka, New Zealand.

SPUMS notices and news

South Pacific Underwater Medicine Society Diploma of Diving and Hyperbaric Medicine

Requirements for candidates

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

1 The candidate must be medically qualified, and be a financial member of the Society of at least two years' standing.
2 The candidate must supply evidence of satisfactory completion of an examined two-week full-time course in Diving and Hyperbaric Medicine at an approved Hyperbaric Medicine Unit.
3 The candidate must have completed the equivalent (as determined by the Education Officer) of at least six months' full-time clinical training in an approved Hyperbaric Medicine Unit.
4 The candidate must submit a written proposal for research in a relevant area of underwater or hyperbaric medicine, and in a standard format, for approval by the Academic Board before commencing their research project.
5 The candidate must produce, to the satisfaction of the Academic Board, a written report on the approved research project, in the form of a scientific paper suitable for publication.

Additional information

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

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

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

The Academic Board reserves the right to modify any of these requirements from time to time. The Academic Board consists of:
Dr Fiona Sharp, Education Officer, Professor Des Gorman and Dr Chris Acott.

All enquiries should be addressed to the Education Officer:
Dr Fiona Sharp,
249c Nicholson Road
Shenton Park, WA 6008
Australia
E-mail: *<sharpief@doctors.org.uk>*

Key words
Qualifications, underwater medicine, hyperbaric oxygen, research

Minutes of the SPUMS Executive Committee Telephone Conference Meeting held on 01 September 2007

Opened: 0900 hr

Present: Drs C Acott (President), S Sharkey (Secretary), G Williams (Treasurer), M Davis (Editor), C Lee (Committee Member), G Hawkins (Committee Member)

Apologies: Drs R Walker (Immediate Past-President), D Smart (ANZHMG Representative), D Vote (Committee Member), V Haller (Public Officer), F Sharp (Education Officer)

1 Minutes of the previous meeting

Dr Acott moved that the minutes of the SPUMS Executive meeting held on 19 April 2007 be accepted as a true record. Seconded by Dr M Davis with one amendment to renumber paragraph 3.4 as a separate item.

2 Matters arising from the previous minutes

2.1 Items covered in relevant agenda items below.

2.2 Proposed that the Editor's honorarium be linked to CPI.

3 Annual Scientific Meetings

3.1 ASM 2008

3.1.1 Due to the necessary delay in September journal publication a separate mail out of the conference brochure was required at some expense.

3.1.2 Ten attendees have fully registered so far, which is an optimistic sign this far out from the conference. Committee members to notify Dr Acott of intention to attend and their availability to present.

3.1.3 Automatic external defibrillator

Dr Acott proposed purchase of AED by SPUMS. The cost is thought to be $2,000–3,000 and the proposal was supported by the Committee. The purchase should be expensed from general revenue funds.

3.1.4 Dr Acott was recently approached by John Lippman for SPUMS and DAN to consider jointly purchasing an AED for donation to Kimbe Hospital, PNG. This was supported by the Committee on condition that DAN ensure that medical staff are appropriately trained in its use. Funds should be taken from ASM expenses.

3.2 ASM 2009

Dr Sharkey conveyed report from Dr Smart that planning is on track for Pearl Pacific Harbour with Bruce Spiess as guest lecturer.

3.3 ASM 2010

3.3.1 Dr Hawkins has proposed a joint ASM with Asian Hyperbaric and Diving Medical Association. Location is a challenge but possibilities include Bali, Malaysia, Thailand.

3.3.2 A preliminary approach has been made to Mike Gerhardt (NASA Astronaut) as a guest speaker. He has expertise in decompression and neutral buoyancy.

4 Treasurer's report

4.1 Banking has switched from ANZ to St George. Accounts with ANZ are still open but it is intended to close these by the end of October.

4.2 Electronic banking with St George is working very well and has significantly improved efficiency and reduced errors.

4.3 Arrangements for a SPUMS business credit card are in progress. Plan to cancel merchant facilities with AMEX, Diners and ANZ shortly as they are no longer used.

4.4 Dr Williams proposed:

4.4.1 That the Committee consider encouraging members to use internet banking by charging an additional fee for manual transactions.

4.4.2 That the Committee consider using mass e-mailing in order to improve efficiency and decrease administration costs. Dr Hawkins to investigate technical issues and discuss at the next meeting.

5 Journal report

5.1 Drs R Walker and M Davis are both planning to attend the EUBS meeting. The Committee supported the content of the planned EUBS presentation and Dr Davis's proposed way forward with negotiations.

5.2 First 30 volumes are in progress to *Rubicon* and should be available shortly. There is no cost involved. Dr Davis proposed making a small donation to *Rubicon* dependent on progress. This was supported by the Committee.

5.3 Dr Davis highlighted significant concerns with application for ISI listing which considers both content and timeliness. The success of this application is being significantly negatively affected by ongoing difficulties in receiving journal material on time.

6 Education Officer's report

Dr F Sharp unavailable to clarify the role of Professor Gorman on the Education Committee and any interest from others in joining the Committee.

7 Correspondence

7.1 Several pieces of e-mail and telephone correspondence were discussed.

7.2 Dr Acott had received a letter regarding diving medicals being conducted in Europe for tourists arriving in Queensland, who then require a further medical. It is suggested that European doctors should consider applying for registration on the SPUMS diving doctors list. International qualification can be reviewed by the SPUMS Education Committee for recognition on the

list. This letter and response should be published in the Journal.
7.3 A letter from Michael Lang requires formal response.

8 Other business
8.1 SPUMS Diving Medical
Dr Acott requested support from Committee for Dr Mike Bennett to proceed in subcommittee to review the guidelines for Diabetes and for expenses to be met by SPUMS. It is hoped that a progress report could be presented for discussion at the next meeting. The Committee supported the proposal including funding of any expenses incurred.
8.2 ASM Convenor Manual update
Discussion deferred to face-to-face meeting in November.
8.3 Committee Member job descriptions
Each Committee Member to write a job description and provide at the next meeting.
8.4 Tendering for ASM
Long history with this issue. Discussion deferred to face-to-face.
8.5 Website development update
Dr Hawkins discussed several aspects. The website is a technically complicated system. In order to add journal volumes it needs capacity upgrade. Dr Hawkins also advised that it would require a software upgrade but this should be done when the next generation of software becomes available. Dr Hawkins is planning to meet with SQUIZ technicians shortly in order to discuss some issues. An option put forward for consideration was to upload the older journal to *Rubicon* and retain only current journal on our website.
8.6 The following committee positions were confirmed as being up for election at the next AGM – President, Secretary and two committee members (Drs Lee and Vote).

9 Next meeting
The next meeting is planned for 04 November 2007 at Melbourne Airport Holiday Inn.

Closed: 1035 hr

SPUMS Annual General Meeting 2008

The AGM for SPUMS 2008 is to be held at Liamo Resort, Kimbe WNB, PNG, at 1000 hr, Wednesday 28 May 2008.

Agenda

Apologies:
Minutes of the previous meeting:
Minutes of the previous meeting will be posted on the notice board at Liarno Resort and were published in *Diving and Hyperbaric Medicine.* 2007; 37(2): 101-5.
Matters arising from the minutes:
Annual reports:
President's report
Secretary's report
Education Officer's report
Annual financial statement and Treasurer's report
Subscription fees for 2009:
Proposed by the Treasurer, seconded by the Secretary:
Full members AUD$150.00 (internet transaction); AUD$170 (manual/paper-based transaction)
Associate /other members AUD$80 (internet transaction); AUD$100 (manual/paper-based transaction)
Election of office bearers:
President
Secretary
Education Officer
Committee Members (2)
Appointment of the Auditor 2008:
Proposed by the Treasurer, seconded by the Secretary:
Barrett, Baxter and Bye, 60 Albert Road, South Melbourne 3205
Business of which notice has been given:
Nil to date; notice must be received in writing to the Secretary by 31 March 2008

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

<www.hboevidence.com>

Minutes of the Annual General Meeting of the Australian and New Zealand Hyperbaric Medicine Group, Saturday 11 August 2007

Opened: 1700 hr

1 Present

D Smart, D Wilkinson, M Hodgson, B Webb, B Trytko, M Davis, I Dey, M Bennett, G Hawkins, M Walker, J Lehm, S Squires, I Millar (via teleconference)

2 Apologies

B Long, H Macdonald

3 Office bearers

No election required this year.

4 Minutes of the 2006 AGM

That the minutes be accepted (M Davis/D Smart). Carried.

5 Business arising

Issues will be discussed under the current agenda.

6 Address by Chair of ANZHMG (D Smart)

6.1 Funding for hyperbaric medicine in Australia

In August 2006, a further three years of funding for soft-tissue radiation injury and non-diabetic hypoxic problem wounds was provided under Item 3C with Federal Health Minister's approval. This is a good result; however, a new application is required by May 2009 to continue the funding. This will require a considerable amount of data from the HORTIS trial to have been published including the work on radiation injury to the jaw because the French study published last year will cause osteoradionecrosis funding to be vulnerable.

6.2 SPUMS issues

The journal *Diving and Hyperbaric Medicine* continues to have significant difficulties in attracting quality papers. The current September edition is struggling for a major keynote paper. Again I encourage all units in Australia to submit papers to *Diving and Hyperbaric Medicine*. The only way we can get it to a higher level with Index Medicus registration is through publication of high-quality papers. At present the incorporation of EUBS into the *Diving and Hyperbaric Medicine* journal is taking place through international negotiation and discussion with EUBS Executive.

6.3 Research

Recruitment for the HORTIS trials is slow with only a few units in Australia and USA contributing data. There is a need to accelerate recruitment based on the contingency that HORTIS will feed into funding models (especially for MSAC). I encourage all units to contribute to HORTIS and register. Royal Hobart Hospital's contributions are currently in abeyance while we wait for a new monoplace chamber. Once this arrives we should be able to continue our involvement in the trial.

The prospective problem wound study is continuing with second year of data collection now complete. It is interesting that approximately 70% of patients are healed by the end of 12 months after commencing hyperbaric oxygen treatment. Well done to Glen Hawkins for continuing the analysis of these data. Again I encourage all units to participate in enrolling patients.

6.4 Australian Standards

Australian Standards 2299.1 (2007) was completed earlier this year. It should be released for publication within a month. This will be a lead-in to review of the other Standards in the series and also to development of new Standards for use of mixed gas and nitrox diving in the occupational setting. I reported in *Diving and Hyperbaric Medicine* the main changes that have occurred in the Standard.

6.5 ANZHMG list of indications

This list was signed off last year and has been published in *Diving and Hyperbaric Medicine* in 2007.

6.6 Support of the HTNA conference

It appears that support of the HTNA Conference has been slowly waning over the last few years. This includes the medical support and presentations given to the conference. I would encourage all ANZHMG members to work towards providing contributions to the conference even if they are review contributions of an educative nature as a benefit to all who attend the conference.

7 MSAC report and federal government funding issues

Refer to Chairman's address.

8 Hyperbaric Problem Wound Study

Refer to Chairman's address. The minutes will record a strong feeling from those at the meeting that, as these data may be fundamental in the MSAC review of what is currently interim funding, the involvement of all units is imperative.

9 HORTIS

Refer to Chairman's address.

10 ANZHMG/SIG list of approved indications for HBO

This list has been published in *Diving and Hyperbaric Medicine* and will be posted on the SPUMS website. It was decided to review this list every two years, to synchronise with the change in executive positions of ANZHMG.

11 Introductory Course in Hyperbaric Medicine

Associate Professor Bennett reported that the SIG course run from the Prince of Wales was close to capacity this year. Next year's course is to be run slightly later in the year. Dr Squires reported that he had the pleasure of co-ordinating his first course run by SUMU at HMAS Penguin – 76 requested to attend the course with just 26 completing it. Access to this course is difficult for civilian doctors as preference is given to Defence Force personnel. The Medical Officers

Course at the RAH has just finished with good attendance. This course is now run only once a year.

12 Hyperbaric facility accreditation
Discussion regarding a system of accreditation similar to that used in the USA by the UHMS.

13 Australian Standards report
Refer to Chairman's address.

14 Diving and Hyperbaric Medicine (SPUMS Journal)
Plans for a proposed merger of our journal with the journal of the EUBS. Associate Professor Davis and Dr Robyn Walker will attend the upcoming EUBS meeting at which further discussion will take place.

15 Minimum data set
Little progress on this since last year. Dr Wilkinson will re-circulate the list of databases used in units in Australia. Associate Professor Smart will reconsider the parameters of an appropriate minimum data set.

16 Clinical trials for discussion
Several trials were discussed. Emphasis was given to the Chronic Wounds Database. Information from this resource is likely to form the cornerstone of our submission to MSAC when they review the Medicare approval for use of HBO in chronic hypoxic wounds. The need for all hyperbaric units to contribute to this was stressed, and then stressed again.
HORTIS is still open and recruiting for the soft-tissue and prophylaxis arms.
Dr Millar is negotiating a multi-centre approach to the proposed HOLT study. Potential further studies were identified in the fields of cardiac conditioning, acute retinal artery occlusion and forefoot amputation surgery.

17 HTNA issues
Associate Professor Smart offered congratulations for a successful HTNA meeting and thanked the quality input from the invited speakers. Associate Professor Davis co-ordinated the judges for the SPUMS prize for the best HTNA presentation. This was awarded to Jo James from the Prince of Wales for her presentation on malignant otitis externa.

18 Other business
Dr Webb reported that the unit in Townsville had budget approval for a full-time registrar in Hyperbaric Medicine (not specific to Anaesthesia).
Dr Walker reminded people that the SIG has access to $10,000 annually as seed funding for CME activity. She sought ideas as to how this might be utilised. The SIG currently has 190 members and those with the Certificate are now paying annual dues.

Closed: 1740 hr

Dr David Wilkinson, Honorary Secretary, ANZHMG

ANZCA Certificate in Diving and Hyperbaric Medicine

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

Eligibility criteria are:

1. Fellowship of a Specialist College in Australia or New Zealand. This includes all specialties, and the Royal Australian College of General Practitioners.
2. Completion of training courses in Diving Medicine and in Hyperbaric Medicine of at least 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
Chair, ANZCA/ASA Special Interest Group in Diving and Hyperbaric Medicine

Articles reprinted from other sources

Critical Review

Epilepsy and Recreational Scuba Diving: An Absolute Contraindication or Can There Be Exceptions? A Call for Discussion

*Maria do Rosario G. Almeida, *Gail S. Bell, and *†Josemir W. Sander

*Department of Clinical and Experimental Epilepsy, UCL Institute of Neurology, and the National Hospital for Neurology and Neurosurgery, Queen Square, London, United Kingdom; and †Epilepsy Institute of The Netherlands, SEIN, Achterweg, Heemstede, The Netherlands

Summary: Recreational scuba diving is a popular sport, and people with epilepsy often ask physicians whether they may engage in diving. Scuba diving is not, however, without risk for anyone; apart from the risk of drowning, the main physiological problems, caused by exposure to gases at depth, are decompression illness, oxygen toxicity, and nitrogen narcosis. In the United Kingdom, the Sport Diving Medical Committee advises that, to dive, someone with epilepsy must be seizure free and off medication for at least 5 years. The reasons for this are largely theoretical. We review the available evidence in the medical literature and diving websites. The risk of seizures recurring decreases with increasing time in remission, but the risk is never completely abolished. We suggest that people with epilepsy who wish to engage in diving, and the physicians who certify fitness to dive, should be provided with all the available evidence. Those who have been entirely seizure-free on stable antiepileptic drug therapy for at least 4 years, who are not taking sedative antiepileptic drugs and who are able to understand the risks, should then be able to consider diving to shallow depths, provided both they and their diving buddy have fully understood the risks. **Key Words:** Epilepsy—Recreational scuba diving—Seizure.

Recreational scuba diving (using "self-contained underwater breathing apparatus") is a popular sport and it is not uncommon for neurologists to be asked by their patients with epilepsy whether they may dive. People in the United Kingdom, taking antiepileptic drugs (AEDs) for epilepsy, whether or not experiencing seizures, have been banned from scuba diving (Hallenbeck, 1984; Millington, 1985; Sykes, 1994; Bove, 1996; Taylor et al., 2002). The UK Sport Diving Medical Committee considers that the requirements that someone with epilepsy must fulfill before being passed as able to dive are "5 years free from fits and off medication" (UK Sport Diving Medical Committee, 2004). Both the Professional Association of Diving Professionals and the National Association of Underwater Instructors regard a history of seizures as contraindications to diving (NAUI, 2005; PADI, 2006).

Scuba diving is a hazardous sport, as it requires mechanical aids to support respiration, and is performed under water. Essentially, the diver carries a tank of high-pressure air (or suitable gas mixture), and this is delivered to the diver at ambient pressure by means of a regulator. The diver also carries a weight system and a buoyancy control device (BCD). Diving associations advise people to dive with a "buddy," a diving partner who shares mutual responsibility for safety.

Apart from the hazards caused by the marine environment and the risk of drowning, there are three main physiological problems that may occur as a result of exposure to gases at depth. These are decompression sickness or illness (DCI), oxygen toxicity, and nitrogen narcosis. These problems can all occur in any diver; each therefore needs to assess the risk/benefit ratio before diving. Questions that need to be addressed include:

1. What are the physiological risks for anyone scuba diving?
2. Are these risks any greater for a person with a history of seizures?
3. Do AEDs themselves pose a risk for someone scuba diving?

Accepted December 13, 2006.
Address correspondence and reprint requests to Prof. Ley Sander, Department of Clinical and Experimental Epilepsy, Box 29, National Hospital for Neurology and Neurosurgery, Queen Square, London WC1N 3BG, UK. E-mail: lsander@ion.ucl.ac.uk
doi: 10.1111/j.1528-1167.2007.01045.x

4. Are seizures likely to be induced by recreational scuba diving in people with epilepsy controlled by AEDs?
5. Is recreational diving by a person with controlled epilepsy likely to endanger the life of others?
6. What benefits may people with epilepsy derive from scuba diving?

A further physiological problem that could be considered is carbon dioxide toxicity. This is most likely to occur in divers using a closed or semiclosed circuit rebreathing apparatus (DeGorordo et al., 2003); most recreational scuba divers use open circuit apparatus. It may also occur when exercising at depth, or due to breath holding, neither of which is recommended for recreational divers. It will therefore not be considered further. Carbon monoxide poisoning may also affect any diver after a "bad fill," and vomiting from whatever cause could prove fatal.

We looked for evidence about diving and epileptic seizures within the medical literature and by accessing diving websites. A PubMed search of English language articles published between 1984 and 2006 was conducted using the following search terms: (1) epilepsy and diving; (2) seizures and diving; (3) diving fatalities; (4) diving injuries; (5) diving accidents; (6) diving morbidity; (7) diving mortality; (8) diving physiology; and (9) drugs and diving. We found a paucity of evidence on this subject. We also investigated the epidemiology of diving in people with epilepsy, to see whether any theoretical risks are borne out in practice.

PHYSIOLOGICAL RISKS INHERENT TO RECREATIONAL SCUBA DIVING

Decompression sickness/illness

Decompression illness results from the reduction in the ambient pressure surrounding a body (Thalmann, 2004). As the diver submerges, and the surrounding pressure increases, more nitrogen (N_2) is forced into solution in the body tissues as the partial pressure of N_2 increases (Barratt et al., 2002). The tissues become saturated and as N_2 is inert it is removed only by diffusion or blood flow. When the pressure decreases as the diver later surfaces, the dissolved N_2 returns to the gaseous state faster than the blood can remove it. Rapid ascent is considerably more dangerous than a controlled ascent, which allows more time for the N_2 to be removed by the blood flow. The N_2 not removed is liable to form bubbles in the musculoskeletal system (causing "the bends"), and in the marrow of long bones, although whether or not the bubble formation is the cause of the symptoms of DCI is not proved (Hamilton and Thalmann, 2003). If N_2 cannot escape through the airways, usually because of breath-holding, it can rupture into the pulmonary venous system [leading to cerebral arterial gas embolism (CAGE)], the perivascular sheaths or the pleural cavity (Barratt et al., 2002). Asthma and bronchitis can also facilitate CAGE by trapping gas in the lungs (Newton, 2001) (although mediastinal emphysema or pneumothorax are more likely), as can patent foramen ovale and other causes of right to left shunt, (Madsen et al., 1994; DeGorordo et al., 2003) as bubbles are able to pass from the venous to the arterial circulation. CAGE accounts for almost one in four fatalities in recreational divers (Newton, 2001). Patients with CAGE may present with alteration of consciousness, seizures, (Newton, 2001) "stroke"-like symptoms, or paralysis (Bove, 1996). Excess nitrogen can remain for hours in the body, and, although the initial effects of bubbles are mechanical, there may also be secondary biochemical effects of activation of leukocytes, platelets, complement, and the clotting cascade (Barratt et al., 2002).

DCI can, to a large extent, be prevented by avoiding rapid ascent and by use of decompression tables or diving computers. It is, however, a probabilistic event, and could occur on any dive (Madsen et al., 1994). Other risk factors include deep/long dives, cold water, and hard exercise at depth (Thalmann, 2004). DCI can occur even when no rules have been violated, and this is referred to as "undeserved" or "unexpected" DCI. It is said that DCI is "still a mystery in many ways" (Almon and Uguccioni, 1997). It used to be thought that it was possible to spend an unlimited amount of time at depths of 9 m or less (Barratt et al., 2002); while this is no longer held to be true, dive tables indicate that the risk of DCI at depths of less than 10 m is very small, provided the dive is not prolonged (Spira, 1999).

Oxygen toxicity

Hyperbaric oxygen (O_2) exposure is known to cause CNS O_2 toxicity, usually manifested by seizures (commonly focal, but generalized seizures may occur in 5–10% patients (Newton, 2001)); the mechanism is unknown (Chavko et al., 1998). It has been suggested that it may be due to changes induced in cerebral blood flow (Chavko et al., 1998) or to the formation of free radicals from molecular O_2 during metabolism (Green and Leitch, 1985; Newton, 2001; DeGorordo et al., 2003). It is also known that GABA falls after exposure to increased pressures of O_2 (Green and Leitch, 1985).

The risk of O_2 toxicity increases with the pressure of O_2 experienced and the duration of exposure (Emerson, 2002). It occurs more often at depths of 50 m or more when breathing compressed air (Green and Leitch, 1985), but may occur at 2 atmospheres pressure (approximately 10-m depth) or less when pure oxygen is being breathed (Spira, 1999). The overall incidence of O_2 induced convulsions is extremely low (around 0.03% in a hyperbaric chamber) (Hampson and Atik, 2003).

Nitrogen narcosis

Nitrogen narcosis is the narcotic-like effect precipitated by increased partial pressure of inspired N_2 at depth (Emerson, 2002). Although it can happen to any diver (Worf, 2002) and is not entirely predictable, it usually occurs at deeper depths and with more rapid descent, (Emerson, 2002) and resolves with return to the shallows (Worf, 2002). The symptoms increase with depth, starting as light-headedness and euphoria from 30 m, through poor judgment and overconfidence, and hallucinations, to loss of consciousness at great depths (Royal Naval Medical Service, 2004). The behavioral disturbances manifested seem to occur regardless of which inert gas is breathed, and, although the mechanism is not yet elucidated, it is assumed to be similar to those of general anesthetics (Turle-Lorenzo et al., 1999). It may be, however, that nitrogen acts directly by potentiating GABA neurotransmission at the $GABA_A$ receptor, thus producing its narcotic effect (Abraini et al., 2003).

ARE THESE RISKS INCREASED IN SOMEONE WITH CONTROLLED EPILEPSY?

Decompression sickness/illness

There is no published literature to support an association between DCI and epilepsy. Uncontrolled epilepsy could, however, predispose to the development of DCI if a seizure occurred while underwater, thus precipitating an acute ascent (Madsen et al., 1994). It is therefore unlikely that someone with fully controlled epilepsy would be more at risk of DCI than someone without epilepsy. It is possible, however, that CAGE could be precipitated by a fast ascent from as shallow as 10 m if breath holding during a convulsive seizure occurred.

Oxygen toxicity

It is important to try to establish whether people with controlled epilepsy are more likely to suffer from O_2 toxicity, and hence from its seizures, than those without epilepsy. Two case histories have been reported which may suggest that people with epilepsy are more likely to have such seizures in a hyperbaric chamber than those without epilepsy (Emerson and Oxer, 1998). One, an experienced diver, developed DCI after a "dive" in the chamber. On recompression with O_2 she had a generalized seizure preceded by a simple partial seizure, and afterwards an EEG was reported as being abnormal, showing generalized epilepsy. This was reported as "unmasking latent epilepsy." However, as the EEG changes were generalized, and the seizure was of partial onset, it is unclear whether the two were closely related. The second was a female having a therapeutic compression, who had a "grand mal" seizure. She had, however, been treated with high doses of pethidine, a metabolite of which may be proconvulsive. Thus it seems unlikely that either of these cases had an intrinsically altered seizure threshold which was affected by hyperbaric oxygen (and therefore unlikely that these case reports show that people with controlled epilepsy are more likely to suffer from O_2 toxicity and seizures than someone without). A recent case report describes partial seizures developing in a man treated in a hyperbaric chamber, but the patient had recently had surgery for frequent seizures secondary to radiation necrosis following treatment for an anaplastic astrocytoma (Doherty and Hampson, 2005). No other recent histories are available of people with known epilepsy being treated in a hyperbaric chamber. A study in the 1940s found no correlation between preexisting EEG abnormalities and time to convulsion in people exposed to high partial pressures of O_2. Indeed, two patients with gross EEG abnormalities who were diagnosed with epilepsy had no increased tendency to convulse (quoted in Green and Leitch, 1985). One study is reported as showing hyperbaric O_2 treatment producing reduction of seizures in children with epilepsy, but the scientific nature of this study is questioned (quoted in Hardy et al., 2002).

Nitrogen narcosis

There is no reason to suspect that people with a history of seizures would be more likely to suffer from Nitrogen Narcosis than anyone without such a history.

ARE THESE RISKS INCREASED IN SOMEONE TAKING AEDS?

Decompression illness

The secondary biochemical effects of DCI could potentially interact with AEDs. These effects are secondary to the formation of bubbles, however, and are therefore unlikely to take effect until the diver is safely on land. Anyone suffering from DCI should not dive again for one month (Emerson, 2002) by which time the biochemical effects should also have cleared. There is no other reason why DCI should preferentially affect anyone taking AEDs.

Oxygen toxicity

There is no reason to suppose that AEDs would increase the risk of O_2 toxicity. Indeed, in rats, carbamazepine has been shown to exhibit a dose-related protective effect against hyperoxic seizures (Reshef et al., 1991), so people with epilepsy controlled by carbamazepine could potentially also be protected. A case report of CAGE causing seizures in a hyperbaric environment showed that phenytoin also appeared to inhibit seizure activity (Weaver, 1983).

Nitrogen narcosis

Some drugs, particularly alcohol and sedatives, are thought to have an additive effect on N_2 narcosis (Royal Naval Medical Service, 2004). As stated above, the mechanism of N_2 narcosis is assumed to be similar to that of anesthesia with nitrous oxide. The British National Formulary (Joint Formulary Committee, 2004) does not list any AEDs as having interactions with nitrous oxide anesthetics, although it states that nitrous oxide produces an increased sedative effect when general anesthetics are given with anxiolytics and hypnotics. Clearly, if any particular

AED is shown to have a sedative effect, then it would be inappropriate for someone sedated by that AED to dive; this may be difficult to ascertain objectively.

It is possible that AEDs acting on the $GABA_A$ receptor (clonazepam, diazepam, phenobarbital, primidone, topiramate, valproic acid that act directly; tiagabine that inhibits the neuronal reuptake of GABA) may interact with high partial pressures of nitrogen. This could produce unexpected side effects, perhaps including nitrogen narcosis.

OTHER RISKS DUE TO AEDS

It has been argued that people with epilepsy will have impaired performance and reaction time due to AEDs (Millington, 1985); those affected in this way by their AEDs and those taking AEDs known to be sedative probably should not dive.

Biochemical and hematological changes occur in people who dive (Philp et al., 1975), and in people who develop DCI (Jacey et al., 1976). The significance of these changes on AEDs, or indeed on any other prescription or nonprescription drugs, is unknown.

ARE SEIZURES LIKELY TO BE INDUCED BY SCUBA DIVING IN PEOPLE WITH EPILEPSY CONTROLLED BY AEDS?

A large questionnaire study showed that approximately 50% of people with epilepsy report seizure-precipitating factors, such as emotional stress (21%), sleep deprivation (12%) and physical exercise (3%) (Nakken et al., 2005). Consequently several factors operating during a dive may be associated with an increased risk of seizures underwater, because they may alter the seizure threshold. These factors include the seizure-precipitating factors above, as well as hypothermia, hyperventilation, breathing oxygen under increased pressure (see above) (Millington, 1985), and changes in drug metabolism (Fountain and May, 2003). Many of these are only important during diver training.

Up to 30% people with epilepsy may experience stress as a seizure trigger, and some report that the stress of participating in sports may exacerbate seizures (Fountain and May, 2003). Aerobic exercise may occasionally cause seizures, but is more likely to reduce seizure frequency; those whose seizures are exacerbated by exercise generally recognize the association (Fountain and May, 2003). Interictal epileptiform activity has been shown to remain unchanged or decreased during or immediately after exercise, even in some people with exercise-associated seizures (Fountain and May, 2003). Hyperventilation performed at rest may trigger absence seizures and epileptiform activity on EEG, by producing hypocapnia and cerebral vasoconstriction. During exercise, however, hyperventilation is a compensatory response to avoid hypercapnia, is usually not associated with seizure exacerbation, and causes relative suppression of EEG abnormalities (Fountain and May, 2003). However, inexperienced divers tend to hyperventilate more than those who have dived more often, although this is often an indication that further training is required. Tiredness and lack of sleep have also long been recognized as potential seizure precipitants (Spector et al., 2000; Nakken et al., 2005). If any person with epilepsy knows that any of these factors are likely to lower their own seizure threshold, then clearly that person should not scuba dive.

Regular physical exercise induces hepatic microsomal enzymes, and the release of fatty acids into the blood stream may compete with protein binding, leading to a higher free fraction of AEDs with important protein binding, such as phenytoin, valproate, tiagabine, and benzodiazepines. Theoretically it could be advisable to adjust AED doses in patients engaged in regular exercise, but a prospective study found no effects of exercise on the blood levels or rate of metabolism, and no correlation between minor fluctuations in the blood levels and seizure occurrence (Fountain and May, 2003).

While the secondary effects of DCI include biochemical changes, they would be unlikely to provoke a seizure.

IS DIVING BY A PERSON WITH CONTROLLED EPILEPSY LIKELY TO ENDANGER THE LIFE OF OTHERS?

The person with completely controlled epilepsy may be able to decide that the benefits of diving outweigh the small risks of having a seizure. It is imperative, however, that the health and safety of the diving buddy be considered. If a diver has a seizure at depth, the buddy would need to reach the surface quickly, putting himself at risk of DCI (Emerson, 2002). One author quotes "several instances of divers having seizures under water who went onto drown, but in addition a diving buddy also drowned while trying to rescue the convulsing diver" (Bove, 1996), but it is not clear whether the divers who had seizures did so because of epilepsy or because of O_2 toxicity. An Australian study of 100 consecutive scuba diving fatalities found that in only 14% of the fatalities did a buddy remain with the person who died, although a further 20% only separated because of the problem causing the fatality (Edmonds and Walker, 1989).

BENEFITS OF SCUBA DIVING FOR PEOPLE WITH EPILEPSY

People with epilepsy tend to be less active, less physically fit and less likely to participate in sports than the general population and to have more psychological problems (Fountain and May, 2003). A study of a regular exercise program on a small number of people with epilepsy showed that behavioral outcomes were positively influenced by moderate exercise with no impact on seizure frequency; 10 of 14 randomized to exercise were seizure-free before starting the study and remained so throughout the study (McAuley et al., 2001). It is important to realize, however, that this study involved a regular, frequent and supervised exercise regimen. People with epilepsy who wish to engage in recreational scuba diving should build up their exercise tolerance, while remaining seizure-free, before considering scuba diving.

EPIDEMIOLOGY OF DIVING DEATHS IN PEOPLE WITH EPILEPSY

As diving is currently banned for people on AEDs for epilepsy, any epidemiological data will be biased, as the numbers of people with epilepsy who dive will necessarily be very small. People with medical conditions for which diving is contraindicated are, however, known to dive. One study sent anonymous questionnaires, which included a list of medical conditions, to members of 29 Australian diving clubs; 346 replies were received (Taylor et al., 2002). For each condition individuals completing the questionnaire could answer "never," "in the past," or "now and I dive with it." Almost half the divers were overweight (a risk factor for DCI), and 8% had asthma or chronic obstructive airways disease (both of which could precipitate arterial gas embolism) in their history, with 3% with current symptoms. Although none had current seizures, 2 of 346 respondents had a history of epilepsy. Other authors note that divers have commented on how easy it is to avoid the detection of medical conditions during the diving medical examination (quoted in Taylor et al., 2002). Additionally, once medical certification is received, no further assessments are required to continue diving (Strauss and Borer, 2001). The survey of 100 consecutive scuba diving fatalities in Australia and New Zealand found that 9% of victims had been specifically advised by a diving medical expert or dive instructor that they were unfit for scuba diving (Edmonds and Walker, 1989). Altogether 25% had preexisting medical contraindications, including one person with epilepsy (which probably did not contribute to the death) and nine with asthma (which may have contributed to the death in eight cases).

In 2000 and 2001, the Divers Alert Network (DAN) received notification of 2,212 injured divers who were recompressed. Only eight patients were reported to have preexisting central nervous system disease (including seizures, migraine, or central nervous system injury). In the same period, DAN was able to obtain records of 168 diving fatalities in the United States and Canada. Only three of the deaths occurred in patients with a history of seizures (including one recently hospitalized for seizures); the presumed causes of death were "air embolism" (in a subject who ascended rapidly, and in whom no AEDs were found), "drowning" (in a new diver, who struggled at the surface) and "cardiac" (shortness of breath noted on the swim back to shore, in a man with severe coronary artery disease and type I diabetes) (Divers Alert Network, 2002, 2003). The South Pacific Underwater Medical Society records show that, between 1972 and 1999 there were four fatalities in divers with a history of epilepsy (Douglas Walker, personal communication, 2006).

The British Sub-Aqua Club (BSAC) publishes annual reports of diving incidents (Cumming, 2005) in the interest of promoting diver safety. In the last 9 years 3,744 incidents have been recorded, including 161 fatalities. There is often very little information available on the incidents. In this nine-year period the reports of three deaths (of 161) have mentioned convulsions or "fits." One was using a mixture of gases usually employed by technical divers and therefore probably not relevant to recreational scuba diving. One collapsed while on land, but was said to have had a fit while in the water. In the other, postmortem examination showed that he had suffered "something akin to an epileptic fit" while underwater. There is no data to determine whether or not any of these three people had a previous history of seizures. A fourth fatality was related to an oxygen toxicity convulsion.

Nonfatal incidents included 22 with mention of convulsions or fits. Eleven of these were probably oxygen toxicity seizures. Three had a previous history of seizures, but had not declared them. One was due to anaphylaxis, and in the other cases it is not possible to establish whether or not the person had a history of seizures. In total, therefore, 3 of 161 fatalities and up to 10 of 3,583 nonfatal incidents may possibly have been related to epilepsy. Thus there is very little reliable epidemiological evidence to suggest that a past history of seizures does, or does not, imply increased risk to recreational scuba divers.

DIVING AND PEOPLE WITH EPILEPSY

There is little doubt that seizures under water are extremely dangerous, particularly if consciousness is lost. Even if consciousness is not lost, the regulator could be dislodged, and the subject drown (Fountain and May, 2003). The consequences of a seizure could potentially be reduced by using a full face mask, as used by police and technical divers (Hamilton and Thalmann, 2003), instead of the usual separate device kept in the mouth by clenching the teeth. A full-face mask would be more likely to remain on the face than the usual regulator if a seizure should occur.

A seizure involving only loss of awareness could pose problems, as maintenance of position in the water requires subtle changes to be made to the air in the BCD. If these changes are not made there is a risk of accelerated ascent or descent, causing problems with DCI and risking loss of contact with (and therefore rescue by) the dive buddy.

DCI should not otherwise occur more frequently in people with epilepsy, but the treatment may involve hyperbaric oxygen. There appears to be little evidence that O_2 toxicity, either during the dive or during recompression, is more likely to occur in people with controlled seizures. It would seem prudent, however, that people with controlled seizures should not use Nitrox (an oxygen enriched mixture, including less N_2 than air and sometimes used to prevent DCI), in case their propensity to have hyperoxic seizures was increased.

DISCUSSION

In 1985 the Professional Advisory Board of the Epilepsy Foundation of America wrote that they "strongly believe that persons with epilepsy whose seizures are controlled can and should lead full lives without any personal restrictions" and that they should therefore be allowed to dive, but not teach diving, as long as they are fully aware of the risks (Dreifuss, 1985). The flurry of letters in reply to this suggested that many people did not agree (Meckelnburg, 1985; Millington, 1985). Twenty years later, the situation has not changed.

Risk taking is an integral part of life and people with epilepsy, like everybody else, should be allowed to make informed decisions about risk. In the United Kingdom people with epilepsy, including those on AEDs, are allowed to drive a motor vehicle provided they have been seizure free for a year. A seizure while driving at speed could potentially injure far more disinterested people than a seizure at depth, although the latter would most likely kill the diver and endanger the life of the diving buddy. People with epilepsy may decide that the risk is worth taking. The chance of seizure recurrence after a period of remission is difficult to quantify, and is dependent on several factors; a history of tonic–clonic seizures, the occurrence of further seizures after starting AED treatment and use of more than one AED all increased the risk of seizures in a randomized study comparing continued AED treatment with slow withdrawal in people who had been seizure free for at least 2 years (Medical Research Council Antiepileptic Drug Withdrawal Study Group, 1993). The risk of seizures recurring decreases with increasing time without seizures, but the risk is never completely abolished; people with epilepsy who wish to scuba dive must be aware of this. In the MRC AED withdrawal study, of 510 patients who had been seizure-free for at least 2 years and who were randomized to continue AED treatment, 22% had had seizures within 2 years, but the risk declined steadily thereafter (Medical Research Council Antiepileptic Drug Withdrawal Study Group, 1991). We suggest that until more information about the risk is available, an empirical approach would be to delay scuba diving in people on stable AED therapy until at least 4 years have elapsed since the last seizure. The chance of a seizure happening in a subject seizure free for 4 years by chance during a 60-min period under normal, nonstressful conditions would be one in over forty thousand. Although this risk may be increased by an unknown amount in someone under stressful hyperbaric conditions, this could be compared with the risk of DCI occurring in any dive, which is said to be one in five to ten thousand (Newton, 2001).

Data on diving in people with epilepsy who are seizure free (whether or not on medication) are not available in the literature. Objections to diving by people who have been seizure-free for a long time are largely theoretical. The situation is similar to that which was the case for people with diabetes mellitus until the early 1990s. In 1991, however, in response to advances in diabetes care, the UK diving authorities changed their recommendations and allowed certain people with well-controlled diabetes to dive (UK Sport Diving Medical Committee, 2004). The Diving Diseases Research Centre conducted a preliminary open, crossover, controlled study in a hyperbaric chamber to examine the effects of diving on serum glucose levels (Edge et al., 1997), and is conducting a further study using questionnaires on divers with diabetes doing "real life" diving. Although it would not be advisable to try to make people with epilepsy have seizures in a hyperbaric chamber, it could theoretically be possible to try to elucidate some of the presumed affects of pressure on AEDs.

There is anecdotal evidence from many practitioners that people with epilepsy may go to areas of the world where diving regulations are less stringent in order to avoid the diving ban. This is clearly very bad practice, and fatalities are far more likely to occur in these conditions. The BSAC data also confirms that people with known seizures may deny having epilepsy to avoid a ban (Cumming, 2005).

It is not possible to rule out an increased risk in people with epilepsy who are seizure free on medication, and the current data do not allow a precise assessment of the magnitude of any risk. Therefore, we recommend caution when evaluating and advising a patient with controlled seizures who requests permission for scuba diving. For each individual, all risk factors for recurrence or for possible complications should be considered. It is important that the person is aware of all the possible risks, and capable of making the decision. No person should dive if sedated by their drugs, and perhaps diving should be limited to depths no greater than 10 m, as the risks of DCI are minimal at this depth unless breath holding occurs. It has been suggested that diving would be safer if the diving buddy was a fully qualified rescue diver, fully aware of the history of seizures. Anyone who has not been seizure-free for at least 4 years should be strongly advised not to dive. People with epilepsy are at higher risk if they dive than those without epilepsy; however, many people with epilepsy will dive regardless of rules and regulations, often concealing their condition. We suggest potential divers be given the best individualized advice available and that they should be warned of the risks and dangers, so they can make an informed decision.

There may, of course, be legal implications for practitioners in agreeing that individual people with epilepsy may be able to consider recreational scuba diving. It is important that physicians should be aware of the legal implications, and should discuss these with their insurers, particularly in countries with a litigious environment. All discussions with patients who wish to dive should be carefully documented, and it may be appropriate to ask the patient to sign a statement that the risks have been discussed.

This is still a controversial issue, and more research is needed to evaluate the risks. The practitioner can only give the patient the best currently available information, and then the decision as to whether to dive has to be the result of a consensus between the person with controlled seizures, the diving buddy, the insurer, and the family.

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Epilepsy, recreational diving, fitness to dive, review article, reprinted from

Editorial comment

At the British Hyperbaric Association Annual Scientific Meeting, November 2007, in Oban, Argyll, Simon Wigglesworth, Deputy Chief Executive of Epilepsy Action (www.epilepsy.org.uk) presented a paper entitled "Epilepsy and scuba diving – time for a review of the guidelines?" There are at least 30 types of epilepsy and a person may have more than one type. Epilepsy is relatively common, affecting approximately one in every 131 people (0.76%) in the UK.

Wigglesworth pointed out that people with epilepsy were allowed to drive after a seizure-free period (duration differs from country to country), whether on or off medication, and in many parts of the world, including the UK, requirements for a private pilot's licence to fly solo or with a safety pilot tend to mirror the driving regulations. He commented that these are activities that potentially place others at risk in the same way that a diver who fits underwater places his dive buddy and others at risk, and asked why the standards should be any different.

He went on to raise the issue of the Disability Discrimination Act (DDA) in the UK. The DDA makes it unlawful to discriminate against disabled people. Under the DDA, discrimination can occur when:

- a disabled person is treated less favourably than someone else
- the treatment is for a reason relating to the person's disability and
- this treatment cannot be justified.

The DDA also requires employers, service providers and those in education to make "reasonable adjustment" for a disabled person. Failure to do so may also be discrimination. Epilepsy is considered to be a disability under the DDA, and the British Sub-Aqua Club (BSAC) recognises that the DDA applies to the club. Similar legislation exists in many countries.

The current BSAC guidelines for recreational scuba in the UK are that a person with epilepsy must be seizure free and off medication for five years before they are permitted to dive, three years if the fits were exclusively nocturnal. In Australia and New Zealand, the current SPUMS Diving Medical, Appendix A, states that "*a candidate with a history of fits (apart from childhood febrile convulsions), or unexplained blackouts…requires further assessment*." No specific recommendations are provided, but the generally held view of the diving medical community in Australasia has been that a history of or current epilepsy is an absolute contra-indication to scuba diving.

At a time when SPUMS is in the lengthy process of reviewing and revising its diving medical, this review article by Professor Sanders and his colleagues is timely and the views of readers are welcome in the 'Letters' column.

For the Editor's part, I am mindful of the fatality data from my own country, New Zealand, in which 10 out of 229 scuba divers and snorkellers who died between 1980 and 2006, had a history of past or current epilepsy and one a history of unexplained syncopal attacks.[1,2] This is an incidence of 4.4% of all diving-related fatalities, an incidence almost six-fold greater than the prevalence of epilepsy in the general community. In all 11 cases, syncope/fitting in the water was believed to have been contributory to these tragedies.

Michael Davis

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First-aid normobaric oxygen for the treatment of recreational diving injuries [Abstract]

Longphre JM, Denoble PJ, Moon RE, Vann RD, Freiberger JJ

Introduction: First-aid oxygen (FAO_2) has been widely used as an emergency treatment for diving injuries, but there are few studies supporting its efficacy.
Methods: 2,231 sequential diving injury reports collected by the Divers Alert Network (DAN) Injury database from 1998 to 2003 were examined.
Results: 47% (1,045) of cases received FAO_2. The median time to FAO_2 treatment after surfacing was four hours and after symptom onset was 2.2 hours. Persistent complete relief (14%) or improvement (51%) was seen with FAO_2 alone (65% overall response; n = 330). After one recompression treatment 67% of FAO_2 patients reported complete relief compared to 58% of the no FAO_2 group (OR = 1.5, 95% CI = 1.2–1.8). FAO_2 given at any time after surfacing significantly reduced the odds of multiple recompression treatments (OR = 0.83, 0.70–0.98). When FAO_2 was given within 4 hours of surfacing, the OR decreased to 0.50 (0.36–0.69) yielding a number needed to treat of 6. Case severity affected urgency of FAO_2 treatment. Individuals with more prominent symptoms received prompt treatment. Cardiopulmonary, skin, and serious neurological symptoms had shorter delays to FAO_2 ($p < 0.001$).
Conclusions: FAO_2 increased recompression efficacy and decreased the number of recompression treatments required if given within four hours after surfacing.

Center for Hyperbaric Medicine and Environmental Physiology, Departments of Anesthesiology and Medicine, Duke University Medical Center, Durham, NC, USA and Divers Alert Network, Durham, NC

Reprinted with kind permission from Longphre JM, Denoble PJ, Moon RE, Vann RD, Freiberger JJ. First-aid normobaric oxygen for the treatment of recreational diving injuries. *Undersea Hyperb Med*. 2007; 34: 43-9.

Key words
First aid, oxygen, diving, injuries, decompression sickness, decompression illness, DAN - Divers Alert Network, reprinted from

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Alveolar gas composition before and after maximal breath-holds in competitive divers [Abstract]

Lindholm P, Lundgren CEG

The urge to breathe, as stimulated by hypercapnia, is generally considered to cause a breath-hold diver to end the breath-hold, and pre-breath-hold hyperventilation has been suggested to cause hypoxic loss of consciousness (LOC) due to the reduced urge to breathe. Competitors hyperventilate before "Static Apnoea", yet only 10% surface with symptoms of hypoxia such as loss of motor control (LMC) or LOC. We hypothesised that the extensive hyperventilation would prevent hypercapnia even during prolonged breath-holding and we also recorded breaking-point end-tidal PO_2 in humans. Nine breath-hold divers performed breath-holds of maximal duration according to their chosen "Static Apnoea" procedure. They floated face down in a swimming pool (28ºC). The only non-standard procedure was that they exhaled into a sampling tube for end-expiratory air, before starting the breath-hold and before resuming breathing. Breath-hold duration was 284 ± 25 (SD) seconds. End-tidal PCO_2 was 18.9 ± 2.0 mmHg before apnoea and 38.3 ± 4.7 mmHg at apnoea termination. End-tidal PO_2 was 131.7 ± 2.7 mmHg before apnoea and 26.9 ± 7.5 mmHg at apnoea termination. Two of the subjects showed LMC after exhaling into the sampling tube; their end-tidal P_AO_2 values were 19.6 and 21.0 mmHg, respectively. End-tidal CO_2 was normocapnic or hypocapnic at the termination of breath-holds. These data suggest that the athletes rely primarily on the hypoxic stimuli, probably in interaction with CO_2 stimuli to determine when to end breath-holds. The severity of hypoxia close to LOC was similar to that reported for acute hypobaric hypoxia in humans.

Center for Research and Education in Special Environments (CRESE), and Department of Physiology and Biophysics, University of Buffalo (SUNY), Buffalo, NY

Reprinted with kind permission from Lindholm P, Lundgren CEG. Alveolar gas composition before and after maximal breath-holds in competitive divers. *Undersea Hyperb Med*. 2006; 33: 463-7.

Key words
Breath-hold diving, respiratory, physiology, hypercapnia, hypoxia, reprinted from

Critical appraisal

Hyperbaric oxygen therapy reduces muscle tenderness and raises pain threshold in patients suffering from fibromyalgia

Clinical bottom line

1 There was a significant reduction in tender points and visual analog scores (VAS) and a significant increase in pain threshold in the hyperbaric oxygen (HBO) treatment group after the first and fifteenth therapy sessions.

2 There was a significant difference between the HBO and control groups for all parameters except VAS scores after the first session.

Citation

Yildiz S, Kiralp MZ, Akin A, Keskin, I, Ay H, Dursun H, Cimsit M. A new treatment modality for fibromyalgia syndrome: hyperbaric oxygen therapy. *J Int Med Res*. 2004; 32: 263-7.

Lead author's name and e-mail: S Yildiz; <senolyildiz@hotmail.com>

Three-part clinical question

For patients with fibromyalgia (FMS), does the administration of HBO, compared to no specific therapy, result in improvement in symptoms?

Search terms

Algometer, hyperbaric oxygen therapy, fibromyalgia, pain threshold

The study

Double-blinded, randomised controlled trial with intention to treat.

The study patients

Patients with FMS according to the criteria of the American College of Rheumatology.

CONTROL GROUP

(N = 24; 24 analysed) Air breathing at 243 kPa for 90 minutes daily, Monday to Friday to a total of 15 sessions.

EXPERIMENTAL GROUP

(N = 26; 26 analysed) 100% oxygen at 243 kPa on the same schedule.

The evidence

See Table 1.

Comments

1. Outcomes measured only to completion of treatment, no insight into longer-term effects.
2. Other treatment options for FMS were not discussed.
3. Pain and tenderness were the only symptoms measured; no consideration of other FMS symptoms (e.g., fatigue, sleep disturbance, irritable bowel syndrome, stiffness, swelling, muscle spasm) given.
4. No information given on baseline patient characteristics.

Conclusions

This small but well-conducted study suggests that HBO treatment may be of benefit in reducing symptoms of fibromyalgia syndrome. More work is needed to investigate how long such benefits may last.

Appraised by:

Amy Gibbens and Mike Bennett, Department of Diving and Hyperbaric Medicine, Prince of Wales Hospital, Randwick, Sydney.

E-mail: *<amy.gibbens@student.unsw.edu.au>*
<m.bennett@unsw.edu.au>

Appraised Wednesday 18 July 2007

Key words

Critical appraisal, hyperbaric oxygen, hyperbaric research, musculo-skeletal, reprinted from

Source

<www.hboevidence.com>

Table 1
Major outcomes in randomised study of hyperbaric oxygen for fibromyalgia (VAS – visual analog scale)

Outcomes after 15 sessions	Sham group		HBO group		Difference	95% CI
	Mean	SD	Mean	SD		
Number of tender points	12.54	1.1	6.04	1.18	6.50	5.85 to 7.15
Pain threshold (units unknown)	0.84	0.12	1.33	0.12	-0.49	-0.56 to -0.42
Pain (VAS 1–100)	55.42	6.58	31.54	8.34	23.88	19.58 to 28.18

Letters to the editor

Diving medical education

Dear Editor,

Congratulations to Carl Edmonds for his 'Opinion' on diving medical courses in your September issue.[1] This timely and important review is written in his characteristically restrained manner. However, he was a bit hard on "Mickey Mouse courses" that thrive by providing continuing medical education seminars in exotic diving locations. These rarely have specific training objectives but they have introduced this subject to many hospital and family doctors. Someone once said that this was how SPUMS began, but maybe you should check that allegation with the Founder?

As in your associated Editorial, the focus is on the training needed to provide competent medical support for recreational and naval divers but, alas, there was little on the deeper needs of working divers in the offshore oil and gas industry. While some diving doctors in every region are needed to become proficient in this, there is a worldwide problem in that most diving medicine courses follow the basic shallower need and have neither the time nor the budget to teach more.

The European development, created jointly by the European College of Hyperbaric Medicine (ECHM) and the European Diving Technology Committee (EDTC) over the last 10 years, recognises the different needs for training in the distinct clinical areas of hyperbaric and diving medicine. In a nutshell, each specialty has a shared Level I for the Medical Examiners of divers and hyperbaric personnel and, at Level II, moves on to the aspects of diagnosis and recompression common to both groups.

The ECHM is a medical committee that defines the lengthy career training needed for accreditation as a clinical HBO specialist (Levels II, III). This includes the medical management of air and deep recreational divers, particularly those needing treatment in a hospital chamber. These courses are audited by the European College of Baromedicine, University of Malta.

In contrast, the EDTC (a multinational tripartite body of government, employer and trades union representatives, and augmented with doctors) has a medical committee (EDTCmed) that defines the training needed for those who provide medical support for working divers. The appointment of Medical Examiners is largely controlled by individual governments but the content of Level I provides the foundation for all diving doctors.

Beyond Level I there is no viable full-time career in diving medicine and so EDTC defined the training needed by those who are already accredited specialists in a relevant clinical field. For them, Level II is supplementary training and, because decompression is only one of the problems to be met, this training must also include the practical aspects of applied diving physiology and accident management at sea and also provide an emphasis on deep saturation diving. These courses are audited by the Diving Medical Advisory Committee DMAC-EDTCmed (http://www.dmac-diving.org/guidance/DMAC29.pdf) and are recognised as an appropriate basis for training worldwide by the international offshore diving industry (IMCA, the International Marine Contractors Association). For those candidates who are not accredited specialists in occupational medicine, evidence is also required of some appropriate training in that field.

For some years these courses have been approved by DMAC-EDTCmed for Level I (e.g., UHMS) and II status (e.g., University of Stellenbosch) outside the EU but a problem around the world is the gap that exists between, for example, the specific training of some navies and the different needs of commercial diving. At present EDTCmed, DMAC and IMCA are reviewing the need around the world for a regional 'top-up' course to give experienced naval and recreational diving doctors the additional components of EDTC Level II needed to cover commercial diving, but it will be some months before these are implemented.

David Elliott
E-mail: *<Davidelliott001@aol.com>*

Professor Elliott is a Life Member of SPUMS.

Key words
Underwater medicine, training, qualifications, occupational diving, letters (to the Editor)

Recognition of diving medicals in Queensland

Dear Editor,

Recreational divers from various European countries dream of diving the Great Barrier Reef (GBR) once in their lifetime. However, again and again we receive complaints that the fitness-to-dive certifications the divers bring with them from Europe are not considered valid for diving the GBR, and that divers have to go to a local doctor to do the same examination again. In most European countries, divers undergo a diving medical review every year or every few years. Many of these are now conducted by diving and hyperbaric physicians who have met the training standards of the ECHM/EDTC consensus statement (1999).[1] This standard has been described previously in this journal.[2]

We are aware that the Queensland state regulations oblige all tourists to have a medical by a locally accredited diving medicine physician. In Australia, you have achieved a reasonable solution, in that medical examiners of divers (MEDs) whose names appear on the SPUMS Diving Doctors

List (DDL, <www.spums.org.au>) are ‘accredited’, and the medicals coming from these doctors are accepted in Queensland.

We recognise that there must be some sort of guarantee that a diving medical certification is not signed by a doctor with insufficient competence, but we believe that this problem for European divers could be reasonably solved by recognition of our European training standards for diving physicians. To believe that all non-Australian diving medical examiners are not competent is clearly discriminatory.

After discussion with some SPUMS colleagues, including the President, we think that a list of European MEDs trained to the standards of EDTC/ECHM could be inserted alongside the SPUMS DDL. With comment from your side that you consider the training of these doctors and the assessment standards of the EDTC appropriate for recreational divers’ medical certifications, you would probably help to stop the current unjustified and discriminatory practice of the Queensland authorities.

We believe frank discussion and future cooperation would be of interest and value to both SPUMS and the European Underwater and Baromedical Society. It is noteworthy that the UK Health and Safety Executive (HSE) has ceased accrediting MEDs, and the International Marine Contractors Association now relies on the EDTC standards for off-shore divers’ medical support worldwide. Our standards have been presented on two occasions at SPUMS ASMs and they are published on the EDTC website.[1]

Dr Jürg Wendling
Chairperson, Medical Subcommittee,
European Diving Technology Committee (EDTCmed)
Fbg. du Lac 67, CH - 2502 Bienne, Switzerland

References

1 Training standards for diving and hyperbaric medicine. Prepared by the Joint Medical Subcommittee of ECHM and EDTC; 1999 <www.edtc.org>.
2 Wendling J, Müller PHJ. Standards for diving in Europe – the present situation. *SPUMS J*. 2004; 34: 141-4.

Key words
Medicals – diving, training, qualifications, fitness to dive, recreational divers, legal and insurance, policy, tourism, letters (to the Editor)

Book reviews

PFO and the diver

Patency of the cardiac foramen ovale: a risk factor for dysbaric disorders?

Constantino Balestra, Frans J Cronjé, Peter Germonpré and Alessandro Marroni

Hard cover, 160 pages
ISBN 978-1-930536-39-5
Flagstaff, AZ: Best Publishing Company; 2007
Price: US$79.00 + P&P
Copies can be ordered online from <www.bestpub.com.> or from Best Publishing Company, P O Box 30100, Flagstaff, AZ 86003-0100, USA
Phone: +1-928-527-1055
Fax: +1-928-526-0370
E-mail: <divebooks@bestpub.com>

This is a highly specific review of a relatively controversial topic in diving medicine by a research group that has published extensively in this area previously. Naturally its focus is largely on the group’s own studies. Amongst other issues, it attempts to address the risk of patent foramen ovale (PFO) in divers and whether there is a significant correlation with MRI abnormalities previously reported in the literature or abnormalities in neuropsychometric testing results.

It does not purport to be a reference text on the pathophysiology of decompression illness and limits its discussion largely to those aspects of decompression illness where paradoxical embolisation of bubbles across a patent PFO may be relevant. Other clinically related conditions where PFO is not relevant, e.g., pulmonary barotrauma and arterial gas embolisation, are not addressed.

It is a hardcover monograph printed on glossy paper with an extensive reference section. The quality of the numerous figures and illustrations is excellent. Disappointingly there are a few obvious typographical errors.

The text is divided into three main sections. The first section (chapters 1 and 2) provides an introduction to dysbaric disorders and a brief discourse of the risks of scuba diving relative to other sporting activities. In the second section, chapter 3 reviews the embryology of the heart and the development of the foetal circulation. The subsequent chapters (4–12) detail the investigations and methodology used by the authors in PFO detection, relating the presence of PFO to decompression illness (DCI), changes in the size and even the presence of PFO over time, intracranial MRI abnormalities and neuropsychometric testing abnormalities in divers and fractal analysis of MRI abnormalities.

The final four chapters (13–16) draw conclusions, de-emphasise the patency of cardiac foramen ovale as an independent risk factor for DCI and emphasise the importance of reducing venous gas bubble production. Possible methods of doing so through deeper stops and/or slower ascents are suggested.

It is of note that a recent review reprinted in this journal cast doubts on the validity of deeper stops.[1] In what is evidently an evolving area the results of the authors' ongoing studies are awaited with great interest.

The final (third) section is an extensive, alphabetical list of references.

With the possible exception of the chapter on fractal analysis, I found this text generally very readable and thought provoking. It provides an excellent update on recent research in a fascinating area of dive medicine. Despite its apparently narrow focus this monograph will find general appeal amongst more than the hyperbaric medicine community; it should be of interest to all involved in diving medicine, particularly those who have ever been perplexed by the severity of decompression illness in a patient following a relatively trivial decompression exposure. I suspect that would include most of us.

Dennis Boon von Ochsée
Department of Anaesthesia, Christchurch Hospital, NZ

Reference

1 Fock A. Deep decompression stops. *Diving and Hyperbaric Medicine*. 2007; 37: 125-32.

Key words
Patent foramen ovale (PFO), diving, decompression sickness, decompression illness, research, book review

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The oxygen revolution

Paul G Harch and Virginia McCullough

Hard cover, 288 pages
ISBN 978-1-57826-237-3
Long Island City, NY: Hatherleigh Press; 2007
Price: US$25.95 + P&P
Available from Best Publishing Company
E-mail: <divebooks@bestpub.com>
Copies can be ordered online from <www.bestpub.com>

The oxygen revolution is a 256-page text by Paul Harch, described as a pioneer of hyperbaric oxygen therapy (HBOT) and a medical maverick, and co-authored by ghost writer Virginia McCullough. The book is written very much for patients and their families to help them understand what HBOT is and how it is thought to work. Harch makes a clear distinction between the acute treatment of decompression illness and delayed treatment at lower pressures, which may help patients with traumatic brain injury or strokes or cerebral palsy.

There are many amazing anecdotal cases presented but, unfortunately for a scientific reader, the book is weak on controlled studies on humans. Harch states "*this current fashion in medicine of evidence-based analyses is extremely limited*." Such statements will not help the case for the acceptance of HBOT in the medical community.

While the dramatic successes are interesting, there needs to be a balance, at least presenting the numbers of patients in his case series with any particular condition that made little or no improvement after HBOT. HBOT may well have a major part to play in many medical conditions in the future, and Harch falls only just short of suggesting whole hospitals have a "dry dive" each day, but more hard evidence would be very useful.

As one who has spent six weeks in HBOT myself, I found my surgical wound in an area of radiotherapy healed beautifully, but the possible gains in intelligence and scalp hair re-growth mentioned in the book were sadly over enthusiastic.

Ian Thomson, FRACS
Vascular Surgeon, Dunedin Hospital

Travel medicine

There is an interesting report in the *New England Journal of Medicine* on the relationship between diseases in travellers returning from various developing regions of the world.

1 Freedman DO, Weld LH, Kozarsky PE, Fisk T, Robins R, von Sonnenburg F, et al. Spectrum of disease and relation to place of exposure among ill returned travellers. *NEJM*. 2006; 354(2): 119-30.

SPUMS Annual Scientific Meeting 2008

Dates: May 24 – 31

Venue: Liamo Resort, Kimbe WNB, Papua New Guinea

Guest speakers:

Professor Alf Brubakk
Associate Professor Richard Moon
Dr David Williams

Themes:

The Treatment Tables
Tropical/Envenomation Medicine Update
Resuscitation Update

Alf Brubakk is from the Norwegian University of Science and Technology in Trondheim, Norway, and was one of the editors of the 5th edition of Bennett and Elliott's *Physiology and medicine of diving*. Richard Moon is Associate Professor of Anesthesiology at Duke University Medical Center, USA, and Medical Director of DAN International. David Williams is a research scientist attached to the Australian Venom Research Unit at the University of Melbourne, Australia. His primary interest is in the management of the envenomed victim in tropical countries.

For registration go to the SPUMS website: <www.spums.org.au>
click on 'Conference Registration'. Early registration/booking is recommended.

Abstracts for presentations are very welcome and should be submitted to the Convenor before 30 April 2008 as a Word file of up to 250 words (excluding references – 4 only) and with only one figure.

Conference attendees will be able to receive CME points from relevant medical bodies (RACGP, ANZCA, NZCGP, etc).

Convenor: Dr Chris Acott
E-mail: <cacott@optusnet.com.au>
Telephone: +61-(0)8-8431-2295
Facsimile: +61-(0)8-8431-8219
Mobile: +61-(0)412-618417

2008 ROYAL AUSTRALIAN NAVY MEDICAL OFFICERS' UNDERWATER MEDICINE COURSE

Dates: 10-21 November 2008
Venue: HMAS Penguin, Sydney
Cost: $1833.00 (tbc)

The Medical Officers' Underwater Medicine Course seeks to provide the medical practitioner with an understanding of the range of potential medical problems faced by divers. Considerable emphasis is placed on the contra-indications to diving and the diving medical, together with the pathophysiology, diagnosis and management of the more common diving-related illnesses.

For information and application forms contact:
The Officer in Charge, Submarine & Underwater Medicine Unit, HMAS PENGUIN,
Middle Head Road, Mosman, 2088 NSW, Australia
Phone: *+61-(0)2-9960-0572*
Fax: *+61-(0)2-9960-4435*
E-mail: *<Scott.Squires@defence.gov.au>*

The Hyperbaric Research Prize

The Hyperbaric Research Prize has been introduced to further encourage the scientific advancement of hyperbaric medicine and will be 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$ 10,000.00 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*
Email: *<samir.desai@palmettohealth.org>*

BRITISH HYPERBARIC ASSOCIATION ANNUAL MEETING 2008
Preliminary notice

Dates: November 2007 (dates to be confirmed)
Venue: Aberdeen, Scotland

For information contact:
Dr John Ross, Hyperbaric Medicine Unit, Aberdeen Royal Infirmary, Foresthill, Aberdeen AB25 2ZN
Website: *<www.hyperchamber.com>*

ROYAL ADELAIDE HOSPITAL DIVER MEDICAL TECHNICIAN (DMT) & DIVING MEDICAL OFFICER COURSES 2008

DMT Courses
March/April 2008
Unit 1: 31 March – 4 April
Unit 2: 7 – 11 April
Unit 3: 14 – 18 April

November/December 2008
Unit 1: 24 – 28 November
Unit 2: 1 – 5 December
Unit 3: 8 – 12 December

DMT Refresher courses 2008
3 – 7 March
27 – 31 October

Medical Officers Course 2008
Basic: 16 – 20 June
Advanced: 23 – 27 June

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>*

AUSTRALIAN and NEW ZEALAND COLLEGE OF ANAESTHETISTS
Annual Scientific Meeting 2008

Dates: 3 to 7 May 2008
Venue: Sydney Convention Centre, NSW

Title: What anaesthetists and divers have in common
Chair: Margaret Walker

1 The uptake, distribution and elimination of a novel anaesthetic agent – nitrogen: A/Prof. Mike Bennett
2 Rebreather diving – a portable anaesthetic machine with a twist: Dr Simon Mitchell
3 A tale of narcosis: Dr David Wilkinson
4 A sad ending – the limits of rebreather performance: Dr Simon Mitchell

There will be a diving and hyperbaric medicine Special Interest Group session during the meeting.

For additional information contact:
E-mail: *<emmab@icmsaust.com.au>*
Website: *<www.anzca.edu.au>*

The Australia and New Zealand Hyperbaric Medicine Group

Introductory Course in Diving and Hyperbaric Medicine
31 March to 11 April 2008
Prince of Wales Hospital, Sydney, Australia

Course content includes:

- History of hyperbaric oxygen
- Physics and physiology of compression
- Accepted indications of hyperbaric oxygen
- Management of decompression illness
- 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-(02)-9382-3880*
***Fax:** +61-(02)-9382-3882*
***E-mail:** <Gabrielle.Janik@sesiahs.health.nsw.gov.au>*

EUROPEAN UNDERWATER AND BAROMEDICAL SOCIETY
34th Annual Scientific Meeting

Dates: 03 to 06 September 2008
Venue: Graz, Austria

The Graz Hyperbaric Centre was originally planned as a two-compartment hyperbaric operation theatre for baby heart surgery in 1965, it is still one of the largest hyperbaric facilities in Central Europe.

For further information, please visit our website <www.eubs.org> or contact:
Martina Neuhold
Auenbruggerplatz 29/1
8036 Graz, Austria
***Phone:** +43-316-385-81923*
***Fax:** +43-316-385-3267*

ASIAN HYPERBARIC & DIVING MEDICAL ASSOCIATION
Annual Scientific Meeting 2008 – preliminary notice

Dates: 15 to 17 May 2008
Venue: Cat Ba Island, Vietnam

For additional information contact:
Dr (‘Tony’) Lee Chin Thang
Medical Director, Hyperbaric Health Asia
***E-mail:** <hyperbarichealth@gmail.com>*

UNDERSEA and HYPERBARIC MEDICAL SOCIETY
Annual Scientific Meeting 2008

Dates: 26 to 28 June 2008
Venue: Salt Lake City Marriott Downtown, Utah

Pre-course workshops:
“Decompression and the Deep Stop” 24 to 25 June
“Wound Healing” 25 June

Register online: <www.regonline.com/UHMS-SLC08>
For additional information contact:
Lisa Wasdin
***E-mail:** <lisa@uhms.org>*

HYPERBARIC MEDICINE 2008

Dates: 3 to 5 April 2008
Venue: Columbia, South Carolina

The Hyperbaric Medicine 2008 programme will feature an internationally respected faculty and draw an equally broad audience. Topics will range from emerging new indications for hyperbaric oxygen therapy, case management updates on existing uses and areas of controversy. If you would like to hear from a particular speaker or on a particular topic we would welcome your suggestions.

For further information please contact:
<www.baromedical.com/hbo2008>
Shannon Blanton,
Human Resources Assistant, National Baromedical Services Inc
***E-mail:** <shannon.blanton@palmettohealth.org>*

Instructions to authors

(revised December 2007)

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 3,000 words or fewer. Inclusion of more than five authors requires justification as does more than 30 references per major article. Case reports should not exceed 1,500 words, with a maximum of 15 references. Abstracts are also required for all case reports and review papers. 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 should not be embedded in the wordprocessor document, only their position indicated. No captions or symbol definitions should appear in the body of the table or image.

Table columns should be as tab-separated text rather than using the columns/tables options or other software and each submitted double-spaced as a separate file. No vertical or horizontal borders are to be used.

Illustrations and figures should be submitted as separate electronic files in TIFF, high resolution JPG or BMP format. Our firewall has a maximum size of about 10 Mb for incoming files or messages with attachments. Large files should be submitted on disc.

Photographs should be glossy, black-and-white or colour. Posting high-quality hard copies of all illustrations is a sensible back-up for electronic files. Colour is available at the Editor's discretion 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 October 2007. Website for details: <http://www.icmje.org/index.html>). In this system references appear in the text as superscript numbers at the end of the sentence 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 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.

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

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

Consent

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

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DIVER EMERGENCY SERVICES PHONE NUMBERS

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

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

SOUTH-EAST ASIA
+65-750-5546 (Singapore Navy)
+63-2-815-9911 (Philippines)
+605-681-9485 (Malaysia)

The DES numbers are generously supported by DAN-AP

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

DIVING-RELATED FATALITIES RESOURCE

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

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

It is hoped that other researchers will similarly securely deposit documents relating to diving incidents when they have no further immediate need of them. Such documents can contain data of great value for subsequent research.

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