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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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Abstracts are also required for all case reports and reviews. Letters to the Editor should not exceed 400 words (including references which should be limited to 5 per letter).

References

The Journal reference style is the "Vancouver" style, printed in the Medical Journal of Australia, February 15, 1988; 148: 189-194. In this references appear in the text as superscript numbers.[1-2] The references are numbered in order of quoting. Index Medicus abbreviations for journal names are to be used. Examples of the format for quoting journals and books are given below.

1 Anderson T. RAN medical officers' training in underwater medicine. *SPUMS J* 1985; 15 (2): 19-22

2 Lippmann J and Bugg S. *The diving emergency handbook.* Melbourne: J.L.Publications, 1985

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BOOK REVIEWS

INTERCEPTED LETTERS

SPUMS WORKSHOP ON COMPUTER ASSISTED DIVING 1994

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To obtain Diving Incident Report forms write to DIMS, GPO Box 400, Adelaide, South Australia 5000.

The Editor's Offering

SPUMS is all about education and safety. If you have not already done so please read the *Objects of the Society* on the opposite page.

The main educational effort of this issue is the *Workshop on Computer Assisted Diving*. There is little need to elaborate on the Workshop here as the Editor's ideas are set out in the paper he presented in Rabaul. There were only two written submissions from our membership, both by Americans. One took the form of a long paper which has been heavily edited to its core points and the other describes the steps necessary to modify the PADI Recreational Dive Planner algorithm so that a computer based on it would not give dives much longer than those available from the PADI Wheel. The lack of contributions, except from members of the Executive Committee, from Australasia suggests that either SPUMS members do not use computers or that they, in common with the majority of divers, do not really understand the disadvantages of computers. Everyone knows of the advantages of computers, they give the diver longer underwater on most dives because dives are mostly multi-level and they are convenient. These are stressed in the advertising. A well educated community should be brimming over with people with opinions.

So write to the Editor with your comments on any topic to do with diving and diving safety. Also put your thoughts about asthma and diving on paper and send them to Dr David Davies, the convener of the 1995 Annual Scientific Meeting, whose address appears opposite. Only in this way can the Workshop have available the beliefs of a cross section of the membership.

There is nothing wrong in thinking differently from the received wisdom, if one has facts to support ones views. This is the way that progress is made. When the theory of continental drift, based on the fit of the east coast of South America with the west coast of Africa, was first published in the early 1900s it was pooh-poohed. It was not until the discovery of the mid-ocean ridges in the 1960s that it became acceptable. Now it is fixed dogma. Your ideas may be equivalent.

In this issue we publish the first *Intercepted Letter*. We intend to publish these as a regular feature, but this depends on readers offering up their ideas and beliefs.

While medicos are encouraged, and even forced, to follow the party line in diagnosis and treatment sometimes the party line is not the best for that particular patient. In diving there is no doubt that buddy breathing has sometimes saved lives. Unfortunately it has also cost lives. Not running out of air has saved far more lives than buddy breathing but this simple routine is not followed by all divers. One wonders, as someone who never has, and never intends to, run out of air, how divers can be so stupid as to run out of air underwater when all they need do is look at a gauge and head for home with enough air to see them back safely. Perhaps it is to do with the rapidity of training, though this is unlikely as the British Sub-Aqua Club, which trains it divers for months before certificating them, still has its divers running out of air.

Diving is promoted as fun but in the Editor's experience it has its moments of terror and panic. It takes time to get the experience to be comfortable underwater. Perhaps the party line on various parts of diver training and self-discipline need to be revised. But that means people with what might be considered way out ideas, such as preferring a swimming ascent to buddy breathing, or diving solo rather than with a "buddy" who is many metres away, need to express their ideas. They will have Editorial assistance, if they want it, to express themselves. Lateral thinkers often come up with excellent solutions for long standing problems. Here is your chance to change the way we dive to a safer way.

A further piece of education is Lyndsae Wheen's paper on the costs of hyperbaric treatment for diabetic foot wounds. In these days of cost consciousness in hospitals knowing that a particular treatment saves money for equivalent results would, one would hope, lead to its increased use.

If you wish to educate your hospital board, write to the Secretary of SPUMS for copies of this issue to present to them.

The recent Safe Limits Symposium in Cairns broke new ground in that all those involved in diving were able to discuss matters of concern in an amicable and constructive manner. We will be publishing the proceedings as space becomes available so that those who did not attend will be able to read about this most interesting meeting.

Twenty and more years ago Australian abalone divers were bending themselves at alarming rates and some died. They were unaware of the risks of the way they were diving and things improved with education. It horrified the Editor to read in *Pressure*, the Newsletter of the Undersea and Hyperbaric Medical Society, of the plight of the Miskito Indian lobster divers, exposed without training, depth or content gauges to dives which are almost guaranteed to cause DCI, with many being crippled and frequent fatalities. You can read all about it on pages 237-238. We will be publishing a fuller account in the next issue.

ORIGINAL ARTICLES

THE EFFECTIVENESS AND COST OF OXYGEN THERAPY FOR DIABETIC FOOT WOUNDS

Lyndsae Wheen

Summary

Diabetic foot ulcers present a major healing problem due to the combined effects of hypoxia and infection. The social and financial costs of the problem diabetic foot are substantial. Experimental work has proved that hyperbaric oxygen therapy will improve tissue oxygenation and thus wound healing. Oxygen also has direct and indirect effects in antisepsis. Clinical hyperbaric oxygen therapy has been shown to improve the healing of diabetic foot wounds significantly and to decrease the rate of consequent amputation. In addition, the financial costs involved are lessened when hyperbaric oxygen therapy is used in combination with conventional management of the problem diabetic foot. Further properly randomised and controlled prospective trials are, however, required to evaluate different oxygen therapy regimes and to obtain accurate cost-benefit data.

Introduction

Individuals with diabetes mellitus are predisposed to foot ulceration because of neuropathies, vascular disease and a susceptibility to infection. Loss of sensation from a peripheral neuropathy may lead to unrecognised foot trauma. Diabetic vascular disease slows healing and predisposes to infection. Infections are common in diabetics because of a combination of tissue hypoxia, resulting from ischaemia,[1] and the pathophysiology of diabetes. The latter has not been completely explained, but diabetics have often been shown to have impaired neutrophil phagocytosis and/or intracellular killing.[2]

The prevalence and cost of diabetic foot ulcers

Severe foot disease is present in about 10% of diabetics, with gangrene resulting in one third of these.[3] A retrospective survey of hospitalised diabetics with foot lesions showed that 34% of the patients required a major amputation.[4] Diabetic foot problems account for an average of 44% (range 26-56%) of all amputations.[5-9] Amputations occur at a rate of 59.7/10,000 diabetics/year[7] or 12.8/100,000 individuals/year.[9] Although Swedish investigators have claimed that the risk of amputation in diabetics is no different from that of non-diabetics,[9,10] this is contrary to other surveys. In North America the risk of amputation is 15 times greater in diabetics.[7]

The level of amputation in diabetics is usually below the knee,[6,10] perhaps due to the predominantly small vessel disease that is seen in diabetes. Although diabetes as such does not influence the morbidity or the mortality associated with amputation,[9] the level of amputation affects the rehabilitation and the consequent mortality. Both are improved with lower level amputations.[5,6,8,10]

In the United States of America (USA) the mean hospital stay for amputations is 29.6 days,[7] but in Denmark it is 68 days overall and 81 days for below knee amputations.[5] This difference may perhaps be explained by the different health funding policies in these countries. The frequency of successful healing of below knee amputations also varies between 39% in Sweden[9] and 79% in the USA.[6] A below knee amputation requires subsequent conversion to an above knee amputation in 22% of cases.[8] A survey of amputees in the USA showed that only 77% were mentally and physically fit enough to be given a prosthesis and, of these, successful rehabilitation was achieved in only 90% of unilateral below knee amputees.[8] The success of rehabilitation dropped to 76% with unilateral above knee amputees, to 40% in those who had needed a below knee to above knee conversion and to 45% among all bilateral amputees.

The mortality associated with amputation is also high. In-hospital mortality is between 11 and 13% in the USA[6,8] and 18% in Denmark.[5] The survival of all amputees drops to between 46 and 49% after three years and to between 30 and 31% after five years.[5,8] The incidence of subsequent amputation of the opposite leg varies from between 25 and 33% in Sweden,[9,10] to 45% in the USA.[4]

It is clear that the morbidity and mortality rates of diabetic foot problems are high because of the frequency at with they occur and their common progression to amputation. Consequently, there are associated significant monetary costs. The cost of care of a patient with an infected ulcer requiring prolonged hospitalisation and eventual minor amputation (of three toes) was US$50,000 in 1988.[11] A prospective study of the costs of care of patients with limb-threatening ischaemia treated with vascular reconstruction or amputation in a hospital in the USA in 19781981, with follow-up through 1982, reported mean hospital costs of US$28,374 for successful vascular reconstruction, US$40,563 for primary amputation and US$50,809 for failed reconstruction.[12]

The costs of care of diabetic foot ulcers cannot be considered in context unless the prevalence of diabetes is described. In the USA, it is estimated that 6% of the population have diagnosed diabetes and that another 6% have undiagnosed diabetes.[13] Although the overall incidence of diagnosed diabetes in New Zealand (NZ), estimated at 3% (personal communication, NZ Department of Statistics), is lower than that in the USA, diabetes and its complications are of importance and cost in New Zealand, particularly in the non-European populations. The prevalence of diabetes in Maori, Pacific Island and Asian populations is up to five times that of a similar European population (9.9%, 8.9%, 7.5% and 1.9% respectively).[14] A study of diabetic admissions to Middlemore Hospital in Auckland, New Zealand, during 1987, showed that 49 of the 357 (14%) diabetic patients were admitted for foot disease.[15] These 49 patients accounted for 64 separate admissions, of which 35 (55%) were for foot ulcers and 14 (22%) were for gangrene. The mean length of stay was 33 days, the amputation rate was 31%, the in-patient mortality was 12% and only 64% of the patients had survived two years later. Of the survivors, 24% had undergone further amputations and half of them had become bilateral amputees. The average hospital cost per patient was reported to be NZ$ 12,500.

The significance of hypoxia in diabetic foot wounds

Diabetic foot ulcers are often refractory to conventional treatment because diabetics heal poorly and have both a compromised immune response to infection and inadequate peripheral perfusion. Poor peripheral perfusion and infection will both lead to tissue hypoxia which is associated with poor wound healing.[16,17] Both macrovascular and microvascular diabetic disease leads to hypoperfusion of the capillary bed.[18] Macrovascular disease (atherosclerotic narrowing) causes ischaemia due to decreased blood perfusion. In diabetics, atherosclerosis is typically peripheral, occurring in the tibial and pedal vessels,[18] thus tissue perfusion is least in the foot. Increased arteriovenous shunting has also been seen in diabetics with neuropathic foot ulcers. This is thought to result from a local sympathetic component of the autonomic neuropathy caused by microvascular disease. The increased arteriovenous shunting leads to redirection of blood away from the skin such that the venous oxygen tension approaches that of arterial blood and so the arterio-venous oxygen gradient is greatly reduced.[19]

In the diabetic person there are several mechanisms by which infection and hypoxia are linked. Microvascular disease is seen as thickening of the basement membrane and functional abnormalities which interfere with the transfer of nutrients and the migration of leucocytes out of the capillary.[20] Thus infection control is diminished. Diabetes also leads to decreased resistance to infection via, at least in part, neutrophil dysfunction.[2,21] Infection causes increased oxygen consumption because of the metabolic requirements for oxygen of aerobic micro-organisms and the oxygen dependant killing of certain micro-organisms by neutrophils. This compounds the local hypoxia and predisposes to further infection.[22] Hypoxia decreases resistance to both aerobic and anaerobic infections. In vitro studies of splenic macrophages have shown decreased phagocytosis in hypoxia.[23] Human polymorphonuclear leucocyte (PMN) phagocytosis and killing of certain aerobes (*Staphylococcus aureus, E coli, Klebsiella* sp, *Proteus* sp and *Salmonella* sp) in culture is markedly reduced in hypoxic conditions, but that of other aerobes (*Streptococcus epidermidis*, viridans Streptococci, enterococci and *Pseudomonas aeruginosa*) and anaerobes (peptostreptococci, *Bacteroides fragilis* and *Clostridium perfringens*) is unaffected.[24] Similar inhibition of *S aureus* killing by rabbit PMNs occurs in hypoxia.[25] Rats exposed to hypobaric hypoxia show reduced PMN neutrophilic granulocyte phagocytosis.[26] In addition, an hypoxic environment is ideal for the growth of anaerobic organisms. Hypoxia also affects the action of the aminoglycoside class of antibiotics which require oxygen for their uptake by bacteria. A member of this class, tobramycin, has been shown to be ineffective at killing *P aeruginosa* in an anaerobic environment.[27] The activity of other antibiotics which need oxygen for their action, such as nitrofurantoin[28] and vancomycin,[29] may also be diminished in hypoxic conditions.

Hypoxia, at the levels frequently measured transcutaneously in the non-healing diabetic foot ulcer,[1] retards wound healing. The initiating events in wound healing are coagulation, inflammation and local hypoxia. These are followed by macrophage migration to the wound and phagocytosis of debris and bacteria.[22] Diabetics appear to have an intrinsically decreased inflammatory response and leucocyte function.[30] Hypoxia results in a further reduction in phagocytosis by macrophages.[23,25] Although some investigators believe that macrophages release an “angiogenesis factor”, which may be lactate, in response to hypoxia,[31] others argue that the oxygen gradient across the wound is the signal for angiogenesis.[32] Hypoxia appears to stimulate in vitro growth and sprouting activity of arterial endothelium.[33] Whichever stimulus predominates, wound healing continues by fibroblast proliferation with collagen synthesis by fibroblasts and capillary growth.[22] Fibroblasts and capillary buds move together across the wound as cross-linked collagen is established as a “scaffolding” for new capillaries. Hypoxia inhibits in vitro fibroblast proliferation and the hydroxylation of proline to hydroxyproline (procollagen).[34] The tensile strength of healing skin wounds is proportional to the collagen-hydroxyproline content and is seen to be lowered in hypoxia. [17]

The role of oxygen therapy in diabetic foot wounds

Correction of any hypoxia may improve otherwise slowed wound healing. Tissue oxygenation can only be improved by increasing the partial pressure of oxygen in the inspired gas and hence the arterial oxygen pressure.[35] The oxygen tension in non-healing wounds has been measured at between 10 and 20 mm Hg, compared with an oxygen tension in normal tissue of between 40 and 52 mm Hg.[35.36] Breathing 100% oxygen at 1 atmosphere (bar) has been shown to raise the oxygen tension in such a wound from 19 mm Hg to 85 mm Hg. Administration of hyperbaric oxygen (HBO) to a series of patients with ischaemic and hypoxic wounds showed locally increased oxygen tension, from between 10 and 20 mm Hg to over 30 mm Hg.[36] The oxygen tension in infected bone (between 19 and 23 mm Hg) can be increased by HBO to a level (between 96 and 111 mm Hg) above that in normal bone (between 44 and 46 mm Hg).[25]

Raising the wound oxygen tension has beneficial effects on the local microcirculation. Studies of an experimentally induced compartment syndrome in dogs demonstrated that HBO reduced the oedema present.[37] Oedema, resulting from injured and ischaemic tissue, increases the diffusion distance from capillaries to cells. Diabetic microangiopathy also causes oedema because affected vessels show an abnormally increased permeability.[20] Between 1 and 2.5 bar, oxygen acts directly on blood vessels to cause vasoconstriction.[38] This lowers the transmural pressures acting across capillaries and so fluid leakage and oedema are reduced. It appears that at pressures above 2 or 2.5 bar, oxygen causes vasodilation.[38] In addition, the microcirculation is improved by the effect of hyperoxygenation on red blood cell rigidity. Red blood cell flexibility, measured as an ability to pass through a 3m filter, was shown to increase significantly with HBO.[39] Red cell deformability is important in decreasing the viscosity of the blood in the microcirculation.

The cellular events leading to wound healing are also improved with hyperoxygenation. In culture, maximal fibroblast proliferation occurs at a tissue oxygen tension of 80 mm Hg.[34] Tissue oxygen tensions above and below this level progressively decrease fibroblast growth. The hydroxyproline content, a measure of collagen synthesis, is also maximal at tissue oxygen tensions of 80 mm Hg.[34] Using an in vitro model of wound healing (fibroblast cells cultured in a chronic hypoxic environment), the effect of simulated clinical HBO treatments was assessed. The cultures were given a schedule of different HBO treatments for 90 minutes a day for four days.[40] Intermittent hyperoxia led to significantly increased numbers of fibroblasts from an hypoxic environment compared with those from a normoxic environment. The hydroxyproline content, however, was not significantly changed by this length of treatment.

The stimulus for new capillary growth appears to be either hypoxia as such, or the oxygen gradient across a wound. Neovascularisation and fibroblast proliferation are closely linked. Capillary growth is required to provide the perfusion, and thus the oxygen, for fibroblast proliferation and synthesis and cross-linking of collagen. The cross-linked collagen is required to form the scaffolding for the new capillary buds. Thus oxygen is required, at least indirectly, for the growth of new capillaries. The revascularisation of full thickness burn wounds in rats was significantly improved, both angiographically and histologically, by intermittent HBO.[41]

Hyperoxia also improves wound healing by its effects in infection control. Hyperoxia leads to increased intracellular and extracellular production of superoxide, hydrogen peroxide and other toxic oxygen radicals. These oxygen radicals are lethal for strict anaerobes, as these organisms lack the detoxifying enzymes superoxide dismutase and catalase.[29,42] Although some investigators have found that aerobic organisms (*S aureus, P aeruginosa, Candida albicans*) are able to detoxify the extra oxygen radicals formed in hyperoxic conditions,[46] others have shown decreased growth of some aerobes (*E coli, P aeruginosa*) in hyperoxic culture.[28] The number of viable *E coli* surviving in experimental wounds in guinea pigs is significantly decreased after two days of 45% inspired oxygen compared with room air (21% oxygen).[43] The in vitro and in vivo growth of *Vibrio* sp is decreased in hyperoxic conditions.[44] The size and number of experimental *Fusobacterium* sp and *Bacteroides* sp abscesses in mice are decreased with HBO.[45] Although some investigators have found that aerobic organisms (*S aureus, P aeruginosa, Candida albicans*) are able to detoxify the extra oxygen radicals formed in hyperoxic conditions,[46] others have shown decreased growth of some aerobes (*E Coli, P aeruginosa*) in hyperoxic culturre.[28]

Oxygen therapy also has indirect effects in infection control. As previously described, PMN bacterial killing is impaired in hypoxic conditions. PMNs use both oxygen-dependent and oxygen-independent mechanisms to kill micro-organisms. The oxygen-dependent killing is initiated by a respiratory burst, which produces superoxide and other potent oxygen radicals and oxidised halide ions, all of which are highly effective microbicidal agents.[29] A study of an experimental *S aureus* osteomyelitis showed that HBO increased PMN killing in osteomyelitic bone to, if not above, that seen in normal bone. HBO had no direct effect on *S aureus* survival.[25] In addition, hyperoxia potentiates the action of certain antibiotics (Table 1).

The mean inhibitory concentration (MIC) and the mean bactericidal concentration (MBC) of nitrofurantoin (which cycles through reduction and oxidation and so requires oxygen for its action) for *E coli* have both been shown to be significantly reduced by the concomitant administration of HBO.[28,47] Although the action of sulphamethoxazole against *E coli* is unchanged,[28,47] the MBC of another sulphonamide, sulphisoxazole, for *Vibrio anguillarum* is significantly reduced by HBO.[44] Hyperoxia potentiates the activity of trimethoprim against *E coli*[28] and *Vanguillarum.*[44] The synergistic action of trimethoprim and the sulphonamides is further enhanced by the use of

TABLE 1

EFFECT OF OXYGEN ON ANTIBIOTIC EFFICACY AGAINST SELECTED MICRO-ORGANISMS

Antibiotic	Organism	Effect of oxygen
nitrofurantoin	*E coli*	potentiation[28,47]
sulphamethoxazole	*E coli*	no change[28,47]
sulphisoxazole	*V anguillarum*	potentiation[44]
trimethoprim	*E coli*	potentiation[28]
	V anguillarum	potentiation[44]
sulphamethoxazole & trimethoprim	*E coli*	potentiation[28]
sulphisoxazole & trimethoprim	*V anguillarum*	potentiation[44]
cephalothin	*S aureus*	no change[28]
cephazolin	*S aureus*	potentiation[48]
gentamicin	*E coli*	no change[28]
	P aeruginosa	no change[28]
tobramycin	*E coli*	no change[28]
	P aeruginosa	no change[28]
		potentiation[47,49]

HB0.[28.44] Cephalosporins also have an antibiotic-specific response to HBO. The anti-*S aureus* effect of cephalothin is unchanged,[29] but that of cephazolin is enhanced by HBO.[48] Aminoglycosides have an oxygen-dependant uptake into bacterial cells; and although some studies indicate that hyperoxia has no effect on the action of tobramycin and gentamicin (against *E coli* and *P aeruginosa*),[28] others have shown that the in vitro and in vivo activity of tobramycin (against *P aeruginosa*) is potentiated.[27,49]

The clinical use of oxygen therapy for diabetic foot wounds

Many reports of the benefit of HBO therapy in the treatment of diabetic foot wounds now exist. Davis et al. presented an historical and pictorial series of seven diabetic patients whose ulcers and underlying osteomyelitis were healed or grafted using HBO.[1] A recent paper reported the successful use of HBO in a complex wound healing problem in a diabetic patient.[50] Barr and Perrins used HBO in the management of 24 diabetic patients with non-healing ulcers.[51] Over an average of about seven months, healing occurred in 67% and amputation was avoided in 18% of these patients. An Italian study showed that, in the treatment of diabetic gangrene, HBO therapy decreased the amputation rate from between 39 (from 1979 to 1982) and 33% (from 1983 to 1987) to only 5% (from 1983 to 1987).[52] Without HBO the healing rates of these major ulceronecrotic lesions dropped from 96% to 67%. Two reports of ten years' experience with HBO in the management of the problem diabetic foot have recently been published.[53,54] In one series, 151 patients with extensive ulceronecrotic lesions were treated with an average of 40 HBO sessions; 130 (86%) achieved complete healing or a more minor amputation than originally planned and only 12 (14%) had worsened clinical findings or a below knee or above knee amputation.[53] The second paper compares an HBO-treated group of 67 patients with a control group of 33 patients.[54] The healing rate was 80% and the amputation rate was 20% in the HBO-treated group, but in the control group the healing rate was only 40% and the amputation rate reached 60%.

There is, as yet, only one prospective and controlled, though not randomised, trial of HBO in the management of diabetic foot wounds.[55] This study included 28 patients, 23 with gangrene and 5 with a perforating ulcer. The treatment group of 18 patients showed a significantly increased healing rate (89% versus 10%) and a decreased amputation rate (11% versus 40%) compared with the control group of 10 patients. Interestingly, the mean hospitalisation period was 20 days shorter (62 versus 82 days) for those patients receiving HBO than those not receiving HBO.

HBO is most successfully used in conjunction with other more conventional measures such as surgical debridement, local wound care, appropriate antibiotic therapy and good metabolic control.[56,57] Not all diabetic patients with foot wounds will benefit from HBO therapy. Adequate peripheral perfusion is necessary, therefore vascular assessment (including palpation, Doppler evaluation of peripheral pulses, ankle perfusion pressure studies, angiography and transcutaneous oximetry) is crucial. Vascular surgery to bypass any large vessel occlusion may be required before HBO therapy can be of any use.[56] Ankle perfusion pressures in the range of 75 to 90 mm Hg are associated with healing with oxygen therapy.[58] Transcutaneous partial pressures of oxygen ($TcP0_2$) can be used to predict healing with HBO. Although some authors believe that only TcP02 measurements made during HBO treatment are predictive,[59] others argue that those made while breathing ambient air or 100% oxygen at ambient pressure can be used to predict outcome.[58] The ratio of wound to reference TcP02, measured in air, is particularly useful in predicting healing outcome: a ratio in the range of 0.20 to 0.85 indicates probable healing with oxygen therapy.[58]

The risks to the patient from HBO are those due to pressure and those due to oxygen. Overpressurisation of any gas trapped in a cavity such as the lungs, sinuses, ears and teeth, can result in barotrauma.[60] Oxygen at higher pressures than 0.21 bar is a toxic gas and so HBO therapy has the potential to produce toxic effects. The manifestations of oxygen toxicity are seen in the central nervous system at partial pressures of over 2 bar. Lung changes develop more slowly and at lower pressures. The risk of toxic effects from oxygen becomes greater as inspired partial pressures of oxygen and time are increased.[60] The

HBO treatment regimens used for wound healing (generally 100% oxygen at 2 to 3 bar for 1.5 to 2 hours daily) avoid serious and irreversible toxic and pressure effects.[61] None of the patients treated with HBO in the studies reviewed suffered from treatment-related problems.[51-55,62]

The costs of HBO therapy for diabetic foot wounds

Cianci et al. published an economic analysis of HBO therapy for problem foot wounds in the USA in 1988.[62] There were 19 diabetic patients in the study; 13 (68%) with limb-threatening lesions. To provide adequate peripheral perfusion for HBO therapy to be used, vascular surgery was required for 8 patients, 42% of total. These 8 were 62% of those with more serious disease. Patients with limb-threatening wounds had a longer mean hospital stay (42 days versus 35 days) and a greater mean number of HBO treatments (40 versus 38) than the group of diabetics as a whole. Successful salvage of the limb was achieved in 17 (89%) of all the diabetic patients and in 11 (85%) of those that had been potential amputees. The charges for those patients with more severe disease (mean HBO cost US$13,456 and mean total hospital charges US$40,697) were higher than the whole group average (mean HBO cost US$12,668 and mean total hospital charges US$34,370). These costs compare favourably with the cost of an acute amputation in 1986 (US$40,563).[12] Rehabilitation expenditures are an additional major cost following amputation. Cianci et al. report that the costs of rehabilitation approached US$40,000[62] and hence the total cost of amputation and rehabilitation in 1988 was in the range of US$50,000 to US$80,000.

Cost analysis of HBO and conventional management of diabetic foot wounds in New Zealand

In order to assess the comparative costs of HBO and conventional management of diabetic foot wounds in New Zealand, the trial of Baroni et al.[55] was used to provide patient outcomes and costed for New Zealand. Bed stay and amputation costs were obtained from a New Zealand public hospital. Information from a public hospital's occupational therapy and physiotherapy departments allowed only crude estimates of in-hospital rehabilitation costs to be made. The Artificial Limb Centre provided costs involved in prosthetic supply and training. Costs of prostheses and other equipment are based on those for a below knee amputation and for the first year only. Prostheses and crutches are usually replaced every year. Data from the Royal New Zealand Navy (RNZN) Hospital, which has the only Hyperbaric Unit in New Zealand, were used for bed stay and treatment costs for HBO therapy. The costs of vascular assessment, medical management of diabetes and daily debridement were not included as these procedures were carried out on both groups of patients.

The calculations show that average cost per patient would be significantly less for the group treated with HBO at the RNZN Hospital (NZ$10,565) than for the control group (NZ$38,359).

Average bed stay cost per treatment group patient (NZ$7,440) is approximately one-fifth that per control group patient (NZ$36,900). This is because of two factors. The first is the shorter hospitalisation period of the treatment group (62 days) compared with the control group (82 days). The second factor is the much lower (approximately one-quarter) bed stay cost of the RNZN hospital (NZ$120/day) than the public hospital (NZ$450/day). Even if the bed stay costs of the two hospitals were the same, the shorter period of hospitalisation in the treated group would result in a 19% saving. (Table 4)

The average per patient cost of amputation and first-year rehabilitation is NZ$405 for the treatment group and

TABLE 2

COSTS OF CONVENTIONAL MANAGEMENT OF DIABETIC GANGRENE IN NEW ZEALAND

Control Group 10 patients
Outcomes **Healed** 1 patient **Amputation** 4 patients **No change** 5 patients
Mean hospitalization period 82 days

Costing item	**Number**	**Cost/item (NZ$)**	**Total cost (NZ$)**
Bed stay	820 days	450	369,000
Theatre costs amputation	4	593	2,372
Occupational therapy input	4	113	452
Physiotherapy input	4	64	256
Walking frame	4	100	400
Crutches	8	89	712
Prosthesis supply and training	8	1,300	10,400
Total			**NZ$383,592**

Average cost per patient NZ$38,359

TABLE 3

COSTS OF HBO WITH CONVENTIONAL MANAGEMENT OF DIABETIC GANGRENE IN NEW ZEALAND BASED ON RNZN HOSPITAL BED DAY COSTS.

Treatment Group l8 patients
Outcomes **Healed** 16 patients **Amputation** 2 patients **No Change** None
Mean hospitalization period 62 days
Mean HBO treatments 34

Cost item	Number	Cost/item (NZ$)	Total cost (NZ$)
Bed stay	1,116 days	120	133,920
HBO treatment	612	80	48,960
Theatre costs amputation	2	593	1,186
Ocuupational therapy input	2	113	226
Physiotherapy input	2	64	128
Walking frame	2	100	200
Crutches	4	89	356
Prosthesis supply and training	4	1,300	5,200
Total			**NZ$190,176**

Average cost per patient NZ$10,565
Saving per patient NZ$27,794

TABLE 4

COSTS OF HBO WITH CONVENTIONAL MANAGEMENT OF DIABETIC GANGRENE IN NEW ZEALAND BASED ON PUBLIC HOSPITAL BED DAY COSTS.

Treatment Group l8 patients
Outcomes **Healed** 16 patients **Amputation** 2 patients **No Change** None
Mean hospitalization period 62 days
Mean HBO treatments 34

Cost item	Number	Cost/item (NZ$)	Total cost (NZ$)
Bed stay	1,116 days	450	502,200
HBO treatment	612	80	48,960
Theatre costs amputation	2	593	1,186
Ocuupational therapy input	2	113	226
Physiotherapy input	2	64	128
Walking frame	2	100	200
Crutches	4	89	356
Prosthesis supply and training	4	1,300	5,200
Total			**NZ$558,456**

Average cost per patient NZ$31,026
Saving per patient NZ$7,333

NZ$1,459 for the control group. This difference is due to the significantly lower amputation rate in the treatment group (1.1/10 patients) than in the control group (4/10 patients).

Despite the additional cost of HBO therapy (an average of NZ$2,720/patient) for the treatment group, the lower bed stay, amputation and rehabilitation costs result in lower total average cost per treatment group patient compared with the control group. These calculations, using known treatment outcomes,[55] and applying NZ hospital and HBO treatment costs, shows that HBO therapy is a cost-effective adjunctive treatment to the conventional management of diabetic foot wounds. Further properly randomised and controlled prospective trials are required to evaluate different oxygen therapy regimes and to obtain accurate cost-benefit data.

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This paper is the thesis submitted for the South Pacific Underwater Medicine Society's Diploma of Diving and Hyperbaric Medicine, which was awarded to Dr Wheen.

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THE WORLD AS IT IS

SAFE LIMITS SYMPOSIUM

This meeting was was held in Cairns from 21/10/94 to 23/10/94 by the Diving Workplace Health and Safety Committee of the Queensland Department of Employment, Vocational Education, Training and Industrial Relations, which makes recommendations on workplace health and safety standards for the Queensland Diving Industry.

The symposium aims were to explore the health and safety implications for the Queensland diving industry of the risks associated with multiple dives during multiple days of diving, post-diving altitude exposure and of Resort Diving. From these discussions the participants were to produce conclusions which were to be internationally valid, relevant to Queensland and form a basis for recommendations by the Diving Industry Committee to the Division of Workplace Health and Safety.

It was the first time in Australia that Diving Doctors had met with representatives of the Recreational Diving Industry to discuss the problems of diving accidents, their frequency and the best ways to cope with making diving as safe a recreation as possible. Two full days of presentations were followed by some hours discussion to arrive at the conclusions. There was a remarkable degree of consensus about these in spite of the widely differing viewpoints from which diving safety was being discussed by the more than 100 registrants.

The Safe Limits symposium papers are available as a bound volume available, while stocks last, from

Ms Sylvie Munson, Council Secretariat,
Division of Workplace Health and Safety,
PO Box 69, Brisbane, Queensland 4001, Australia.

The SPUMS Journal has asked permission to reprint the symposium papers to bring this important initiative to the attention of the membership around the world. The papers will appear over the next year or so, depending on space available. The first one, the Official Summary appears in the adjacent column.

SAFE LIMITS: AN INTERNATIONAL DIVE SYMPOSIUM OVERVIEW AND CONCLUDING SESSION

Des Gorman

Introduction

A comprehensive range of subjects were discussed over the 2 days of formal symposium sessions. The most notable feature of this debate was the friendly context and the considerable consensus. This is noteworthy in that previous gatherings of this type have been recipes for "bun-fights".

The attendance at the Symposium was impressive in its breadth, Government Agencies (Queensland, Victoria, South and Western Australia were represented), commercial divers and their union, recreational divers and members of their support industries, "technical" recreational divers and medical practitioners (with delegates from all the Australian States and New Zealand and all of the members of the SPUMS, South Pacific Underwater Medicine Society, Executive).

Similarly, the presentations were of a general high standard and it is reasonable to conclude that the interest of delegates was sustained throughout the program.

Special appreciation must be expressed here for all the officers of the Queensland Government Division of Workplace Health and Safety involved in conduct of the symposium and in the preparation and introduction of the Code of Practice for Diving. The agreement at the concluding session of the symposium on the suitability of this Code to act as a template for the rest of Australasia is testimony to the merits of the Code and its authors.

This review of the concluding session of the symposium will address each of the 5 principal debating points and briefly mention other topics of concern.

An Australian Code of Practice for Diving

This debate was prefaced by brief reports from Mr Terry Cummins, Mr Steve Sinclair and Dr Tony Slark. It was agreed that an Australasian-wide Code of Practice for Diving was highly desirable and that the Queensland Code was a very suitable template. Regardless of legislation, it was also agreed that the Code would be most effective if it were essentially self-regulated.

Mr Cummins reported that Dive Australia is already preparing such a draft Code.

Common diving practice

This debate was prefaced by brief reports from Dr Chris Acott, Ms Nancy Cummins and Mr Colin Hodson. Although the original proposition was related specifically to decompression schedules, the presenters and the symposium delegates considered this too restrictive and extended the discussion to include all diving practice. In contrast to the options of a common standard or the status quo, it was agreed that an industry-wide group (including representatives of the medical profession through SPUMS) should be established and funded by the participants to collate and disseminate information on diving practice, with special attention to established risks.

The consensus was also that the response of individuals and groups to these data should be left to their discretion.

Training of medical professionals

This debate was prefaced by brief reports from Dr Peter Chapman-Smith, Mr Drew Richardson and Dr John Williamson. It was quickly agreed that a medical practitioner needed to be trained in diving medicine to undertake an assessment of an individual's fitness for diving. The agreement here, from the recreational diving groups, to the consequent limitation of diving fitness reviews to such trained practitioners was obtained on the basis that this only be applied to those areas were there were enough trained practitioners to both meet the local need and to give customers a choice. Fortunately, this condition already exists in most area of Australasia.

SPUMS maintains a list of suitably trained medical practitioners and this list is available to any interested party.

Regulation of Technical Recreational Diving

This debate was prefaced by brief reports from Dr David Davies, Mr Colin McKenzie and Mr Phillip Percival. The symposium quickly supported the argument from the presenters that "technical" recreational diving should be kept separate from the "conventional" aspects of recreational diving and that the introduction and regulation of "technical' recreational divans would be best achieved by an unique Code of Practice.

The current attention of the United Kingdom Health and Safety Executive to this issue was noted and it was agreed that this would provide a very useful template for Australasian Codes. SPUMS also announced that it was going to devote the Society's 1996 Annual Scientific Meeting to a workshop on "technical" recreational diving.

Training of Occupational Divers

This debate was prefaced by brief reports from Mr Garry Ihnen, Ms Judith McDonald and Mr Bruce Thompson. Both these presenters and the symposium in general were certain that the training conducted by the recreational diving training agencies was not appropriate for intending occupational divers, with the single exception of those whose sole diving occupation was to train recreational divers. The scientific divers present reported that they may need to develop specific courses for their needs as they did not "fit well" with either the recreational or occupational training modes.

Other issues

A range of other issues were agreed directly or indirectly. For example, it was universally conceded that the demography and behaviour of the diving community has to be described, in this context, active support of Dr Chris Acott's Diving Incident Monitoring Study and the Divers Alert Network Safe Diver Program were advocated.

Also, it was acknowledged that more feedback from hyperbaric units to dive operators is needed so that these operators can be made aware of the actual outcome of their clients (e.g. those who develop decompression illness after they return to their home state).

Summary

The symposium was a considerable success, both from a logistic and an academic perspective. The social program was similarly enjoyable, more so given the good nature of the entire meeting. The prospects for sound risk-related approach to diving are excellent because of the dialogue established here between the previously often divergent participants.

Again, considerable credit is due to the Queensland Division of Workplace Health and Safety.

Surgeon Commander Des Gorman BSc, MB ChB, FAFOM, Dip DHM, PhD, who was the Symposium Chairman, is Director of Medical Services of the Royal New Zealand Navy. His address is RNZN Hospital, Naval Base, Auckland, New Zealand.

MY BEND

This is the story of one man's decompression illness spoiling a diving holiday. It started on a cold winter's day in southern Australasia when the party boarded a plane for the tropics. We arrived at 2200 and immediately noticed the heat. Standing around the airport we were soon sweating profusely. It was late to bed at the hotel and up early for diving next day.

Our first dive was on an inshore wreck. My buddy had recently recovered from a cold. She had considerable difficulty equalising and by the time we were down the others had carried on with their dive to the expected maximum of about 30 m. As we had spent so long getting down we only went to about 18 m and waited for the others to come up. Our total time for the dive was 41 minutes. Our second dive was two hours later on another wreck. It was a repeat of the first dive, except that my buddy could not get down at all and gave up the dive. Once again the others had carried on so I went on my own to the stern of the wreck and back up to where the others were. The maximum depth for this dive was 34 m with a total time of 39 minutes.

After the dive we were taken to the resort which was to be our home for the next week. After settling in the only thing to do was sit down and have a couple of beers. After tea we also had a couple (or so) of duty free gins to celebrate our arrival.

I woke next morning feeling slightly hung over and after breakfast still felt thirsty so I had a can of lemonade. We had been warned not to drink the water and never thought to take other drinks with us.

That day our dive was on another wreck and I was buddied with a dive instructor. The plan was to go down fairly quickly over the wreck to the stern at about 40 m and make our way back up through the ship. We hoped to have enough air left to dive on a plane after lunch. We made our way down the ship to the stern taking rather longer than I would have preferred. I was already down to about 120 bar, having started with 198 bar, when we rounded the stern and started our ascent from a maximum of 45.1 m. We separated from the others and I was taken through several internal sections of the ship. We made our way steadily up, keeping our computers out of decompression time. By the time we reached shallow water I did not have much air left and used what was left swimming back towards the beach at about 3 m. Had I had more air I would have stayed on the wreck. But I did not worry as I felt the dive, 24 minutes underwater, was quite safe and did not require a longer safety stop.

I was using a Suunto Eon computer, which I was trying out and had not used before. It is air integrated and gives a very large amount of information. With the right interface the dive log can be down loaded into a PC. I had read the instruction book, but during the dive I was more concerned with the details of my air supply and did not take too much notice of the nitrogen loading information. On studying the log later I found that I had gone into decompression time at some stage without realising it. I do not think it could have been for very long. My buddy's computer, an Aladin Pro with a different algorithm, did not go into decompression time at any stage during the dive. Our total dive time was 24 minutes.

We got ashore through the slight surf and changed. After about 20 minutes I began to notice a strange numb feeling in both forearms. This progressed to the legs and within a few minutes I could no longer stand up. I lay down and the dive organiser produced a cylinder of oxygen from a boat that was just off shore and started me on 100% oxygen about 5 minutes after the onset of my symptoms. By this time my skin was tingling over most of my body and my legs felt very strange. Although I could not use them, I felt that I could move them very easily, in fact they felt as if they were floating. I did not lose feeling and had no problems with vision or loss of consciousness.

It was obvious that I was suffering from decompression illness and the dive organiser was ready to take me to the local hospital as soon as the divers were all ashore. After about 20 minutes on oxygen the symptoms all disappeared. I finished the oxygen cylinder and then stood up and walked about. I felt well so it was decided to move to the next dive site before taking me to hospital. This move progressed to getting the divers back to the resort so it was about 5 hours after the onset of symptoms that I got to hospital. I was still pretty much symptom free, apart from a slightly vague feeling, and after several tests it was decided that I should be admitted for the night to breathe oxygen and be evaluated in the morning.

By morning I still felt alright and after evaluation by a different doctor I was released on the basis that if anything happened I should return. I went out and got a taxi to get some money and possibly try to get back to the resort. After driving around for a while I started to get pins and needles in my fingers and felt weak in the legs, so I returned to the hospital.

Eventually I saw the same doctor I had seen that morning. Things were complicated by the fact that the doctor the previous night had put in her notes that she had recommended that I be evacuated to Townsville and I had refused. This misunderstanding upset me as when we had discussed the options I had suggested that as I was symptom free it seemed unnecessary to go to Townsville. The doctor had rung Townsville and later told me the decision had been made for me to stay on the island for the night.

Another call to Townsville and arrangements were made to transport me that night using a jet from Brisbane which could be pressurised to sea level.

Once in Townsville, arriving some 40 hours after my symptoms started, I was admitted and recompressed that day and the next. It was difficult to say how successful treatment was as I had very few symptoms before receiving treatment, just a feeling of vagueness and perhaps some unsteadiness.

After treatment I felt near enough 100% and was released on the morning of the third day in Townsville with warnings not to fly for at least two weeks, and preferably four weeks, and not to dive or go skiing for 6 weeks. This meant an enforced holiday in North Queensland, which partly made up for the ruination of my long awaited trip to the tropics.

I have now returned home with no residual problems and feel unlucky that I had the problem in the first place but lucky to have escaped without any continuing problems.

Lessons to be learnt

The assumed reasons for the bend were a fairy high risk dive pattern combined with dehydration from the effects of alcohol the night before and considerable sweating in the unaccustomed heat.

The first day’s diving turned out to be a shallow dive followed by a deep one, a pattern that is known to be associated with decompression illness (DCI). The next day’s dive was not well managed with most of the time being spent below 30 m and the full dive printout shows that decompression time was incurred at intervals. Deep dives are also known to be associated with decompression illness.

If the three dives had been done using the USN tables the first would have been a no-stop dive, giving a repetitive group of F which would have decayed to D after 2 hours giving a residual nitrogen time (RNT) of 12 minutes and allowing a no-stop dive to 34 m (36 m in the table) of 3 minutes.

The actual dive was for 39 minutes which with 12 minutes RNT gave a bottom time equivalent of 51 minutes. 55 minutes at 36 m gives a USN decompression obligation of 2 minutes at 9 m, 22 at 6 m and 45 at 10 m ! The DCIEM tables give the first dive as a no-stop dive and 6 minutes no-stop time for the second.

The actual second dive has an equivalent bottom time of 59 minutes which is off the DCIEM sport diving tables. For 36 m the maximum dive time displayed is 25 minutes with a decompression obligation of 10 minutes at 6 m and 10 at 3 m.

For the third dive the USN tables would have required 7 minutes at 6 m and 20 at 3 m and it is outside the DCIEM sport diving tables. Computers certainly allow much more time underwater for a multi-level dive but they are not infallible and diving that comes close to the envelope is risky.

Dehydration contributes to DCI risk. The only one sure sign that a healthy person is well hydrated is a good output of colourless urine. Visitors to the topics should drink more non-alcoholic and caffeine free liquids than are needed to slake ones thirst.

Early treatment with 100% oxygen often controls symptoms but unless treatment is continued there is a good, or rather bad, chance of them recurring.

Exercise should be avoided after DCI is diagnosed as movement is known to precipitate DCI. I became normal, only to relapse when off oxygen and walking about.

Those with suspected DCI should be evacuated immediately to hospital and given 100% oxygen and fluids while the need for further transfer is discussed with a hyperbaric unit. The occasional “unnecessary” transfer can, as it would have in this case, shorten the time to recovery after treatment.

Deep diving when worried about ones air supply is asking for trouble as the diver concentrates attention on air supply and can easily neglect depth and time and consequent nitrogen uptake when all the information is in the one display.

My recommendations following the incident would be for dive operators in the tropics to have drinks available for their clients and for them to react more positively in getting anyone suspected of DCI to hospital. The value of having oxygen available was very much proven.

This report is published anonymously and without location details because it is Editorial policy to provide confidentiality for the subjects of such reports.

VICTORIAN AIR FILL SURVEY 1993-1994

Warrick McDonald

Introduction

The Air Fill Survey came from an idea that I had early in 1993. I had been asked by a number of people, including the Coroner and Police, about the number of divers and the number of scuba dives undertaken in Victoria and each time I could only have a guess at the figures. As no one can scuba dive without air the air fill figures will give the minimum number of scuba dives undertaken in Victoria during the study period, July Ist 1993 until June 30th 1994. It must be remembered that some divers carry out more than one scuba dive per air fill.

I believe the figures in this survey, carried out for the Diving Industry of Victoria Association, will provide information about the size of the recreational scuba industry in Victoria.

Methods

Information was collected by telephone, at the end of each month, by myself. The results were randomly checked by talking to different staff members at some establishments and by requesting the figures again at a later date, implying that they had not been supplied.

The individual air supplier's results in this survey are not available for publication. The protection of the providers was of paramount importance to me and therefore a code was used so that only I know individual figures. The information will be kept to enable future surveys to be compared or checked against it.

Results

There were 46 respondents to the survey, consisting of dive shops, cylinder test stations and other compressed air outlets. They were divided into three groups. The first group, the Central area, consisted of 20 outlets, all with 03 telephone numbers, in metropolitan Melbourne. Secondly 14 outlets made up the West area, being all respondents west of a line drawn from the City of Melbourne and running through the heads of Port Phillip, but not including 03 telephone numbers. The final group consisted of 12 outlets in the East area, all respondents east of the line dividing Port Phillip, but not including 03 telephone numbers.

The Central area, metropolitan Melbourne, produced the most air fills but this is to be expected because of the high proportion of air fill stations and of the Victorian population in the area. The East area outlets filled the next largest number of cylinders although it was the smallest group. Again this is to be expected as a lot of diver training is done in Port Phillip, outside the 03 telephone number zone, from the Mornington Peninsula. In all tables the averages of air fills have been rounded to the nearest whole number.

TABLE 1

VICTORIAN AIR FILLS 1.7.93-30.6.94

Area	Air fills	Average per outlet
Central	28,222	1,411
West	21,673	1,548
East	27,811	2,318
Total	**77,706**	**1,689**

Compressors are expensive, a simple calculation shows the following. These costs are a low “guestimate.” For example a 15 cfm high pressure compressor costs approximately $17,000, 4 x high pressure storage cylinders are about $ 3,200, manifold, filling lines, panel etc. are another $1,500.00 giving a total of $21,700.

If one assumes that every fill was sold for $6.00, this requires removing the school training dives which would be costed differently, the staff or owner's fills and any discounted bulk buys before calculating the gross income. The current price for an air fill ranges from $4.00 to $7.00.

These 46 outlets average 1,689 fills, at $7.00 a fill that would be $11,823.00 income. That sounds good, but I am advised by the outlets that the real figure, because of the variable factors, is more like $5.00 per fill and half the number not being paid for directly. Now the income drops to $4,222.50. The running costs to be set against this income are considerable; new filters every 200 hours or so $185.00; oil $90.00 after approximately 400 running hours; valve service about $140.00 after 800 hours; and electricity costs of about $200.00 a month plus the inevitable broken filling hoses and yokes. Overheating or low oil damage that can instantly remove $4000.00 with one grinding clunk.

How long does it take to fill a scuba cylinder ? We know the problems of filling quickly and filling slowly so somewhere in between lies (depending on the day) the perfect time. Let us, for the sake of argument, say 5 minutes a fill. Now this takes into account multiple hose filling panels, because the physical time to connect and disconnect will still be about the same. West and East's figures were largely reported to be taken on the weekends whereas the Central area's outlets are not usually open on Saturday afternoons nor on Sunday. As Central's average

TABLE 2

VICTORIAN AIR FILLS BY MONTH

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Fills	3,406	3,031	3,836	5,396	7,125	7,808	9,813	9,899	11,139	8,196	4,837	3,480
Average	74	65	85	117	155	170	213	215	242	178	101	76

TABLE 3

CENTRAL AIR FILLS BY MONTH

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Fills	1,453	1,325	1,599	2,032	2,554	2,771	3,041	3,264	3,767	2,938	2,054	1,454
Average	74	66	80	102	128	139	152	163	188	147	103	73

TABLE 4

WEST AIR FILLS BY MONTH

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Fills	959	617	1,153	1,480	1,900	2,214	3,170	3,064	3,515	2,088	844	669
Average	68	44	82	106	136	158	226	219	251	149	60	48

TABLE 5

EAST AIR FILLS BY MONTH

	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Fills	964	1,089	1,084	1,884	2,671	2,823	3,602	3,571	3,857	3,170	1,739	1,357
Average	80	91	90	157	223	235	300	298	321	264	145	113

is 1411 air fills this gives 117 hours and 35 minutes working time per year filling tanks. The hours of these outlets vary but it can safely be assumed that the majority of them are retailers and therefore work a 52 hour week. This means that 2 hours and 15 minutes a week are dedicated to air fills. The story changes when we consider the East and West figures, most, as stated to me, are not full time and therefore the majority of air fills were done at the weekend. Consider the difference, 9 a.m. until 6 p.m. for two days equals 18 hours. In the figures supplied by the West this means with their average of 1,548 air fills take up 129 working hours, meaning 7 hours and 9 minutes a weekend are spent filling tanks. The East area had an average of 2318 air fills and this works out at 193 working hours per year resulting in 10 hours and 45 minutes a weekend spent filling tanks.

Air fills are a service for the customer and are a necessary item for a dive school. Unfortunately the industry feeling is that the more air fills an outlet does the more money they are losing !

Diving season

March appeared to be the best month for diving and this seems to give credibility to the belief that the summer season is getting later all the time. Central's much more even graph when compared to the other areas is possibly due to the more stable customer base and full time operation of outlets.

The sudden drop in air fills in the West after March could be attributed to the large swells that battered the West coast for two months. The holiday period having ended, schools returning and the return to the city of holiday makers, would also help to explain the decrease in numbers.

East had a slow start to the season and a sudden drop in April, possibly due to the bad weather or the fact that a number of the outlets are only part time or keep unusual hours.

The Air Fill Survey could now be used by groups, such as SPUMS, to compare the accident/incident rate in Victoria with the number of dives undertaken. This figure then may show if scuba diving in Victoria is that different, as far as safety, from other areas. It has been a belief by many that our cold water and strong currents may cause more cases of decompression illness and especially place in danger many divers that are not trained in Victoria, and then dive here without a familiarisation dive, or dives, under guidance of an instructor or divemaster.

Weather is an obvious factor that slows the number of students enrolling in courses and keeps the qualified divers inside watching television. The diving season basically starts after the AFL Grand Final and ends at Easter. This survey shows that general feeling to be true.

Acknowledgment

I wish to thank the 46 providers who put up with my incessant nagging for the facts.

Warrick K.D.McDonald is a scuba instructor and dive shop owner. His address is A.B.Ocean Divers, 237 East Boundary Road, Bentleigh, Victoria 3204, Australia.

SPUMS NOTICES

SPUMS ANNUAL GENERAL MEETING 1995

will be held at
Castaway Island Resort, Fiji,
on Saturday June 27th at 1600.

Motions, in writing, for discussion at this meeting must be in the Secretary's hands by April 14th 1995.

NEW ZEALAND CHAPTER OFSPUMS ANNUAL GENERAL MEETING 1995

The NZ Chapter Annual Meeting will be held on 7, 8, 9 April 1995 at The Pacific Harbour Motel, Tairua. As usual this will combine a scientific meeting, annual business meeting, and practical diving activities, principally at the Alderman Islands.

Part of the meeting will be devoted to a workshop on fitness for diving so that a New Zealand consensus may then be taken to the SPUMS ASM workshop later in the year. Original papers for a free papers session are now invited from members. We would also be very pleased to hear from New Zealand members of topics they would like discussed.

Enquiries should be addressed to

Dr Chris Morgan, 9 Amohia Street, Rotorua, (phone (07) 347 8350); or Dr Rees Jones, Northland Pathology Laboratory, P.O.Box 349, Whangarei, (phone (09) 438 4243; fax (09) 438 4737); or Dr Mike Davis, P.O.Box 35 Tai Tapu, (phone (025) 332218 or (03) 329 6857, fax (03) 332 8562).

ANNUAL SCIENTIFIC MEETING AND ANNUAL GENERAL MEETING 1995

Castaway Island, Fiji.
Sunday 21/5/95 to Sunday 28/5/95

The Guest Speaker is to be Dr A A (Fred) Bove, Chief of Cardiology at Temple University in Philadelphia. He was the Guest Speaker at Madang in 1982. The Convener of the ASM is Dr David Davies, Education Officer of SPUMS. The theme of the meeting is Fitness to Dive. The Workshop theme is Asthma.

Those wishing to present papers are asked to contact Dr Davies at Suite 6, Killowen House, St Anne's Hospital, Ellesmere Road, Mt Lawley, Western Australia 6050 (Fax 09-370-4541) as soon as possible. The same applies to those wishing to contribute to the Workshop on Asthma, especially if unable to attend the meeting. Dr Davies intends to prepare their written submissions to distribute to those attending the meeting. This means that such contributions will need to be in his hands by the middle of April 1995. Intending speakers are reminded that it is SPUMS policy that speakers at the ASM must provide the Convener with the text of their paper, ready for publication, before they speak.

The Offical Travel Agent for the meeting is Allways Dive Expeditons, 168 High Street, Ashburton, Victoria 3147, Australia. Telephone (03) 885 8863, Toll Free 1-800-338-239, Fax (03) 885 1164. From overseas dial 61-3-before the last 7 digits of the telephone and fax numbers.

S0UTH PACIFIC UNDERWATER MEDICINE SOCIETY

DIPLOMA OF DIVING AND HYPERBARIC MEDICINE.

Requirements for candidates

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

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

2 The candidate must supply documentary evidence of satisfactory completion of examined courses in both Basic and Advanced Hyperbaric and Diving Medicine at an institution approved by the Board of Censors of the Society.

3 The candidate must have completed at least six months full time, or equivalent part time, training in an approved Hyperbaric Medicine Unit.

4 All candidates will be required to advise the Board of Censors of their intended candidacy and to discuss the proposed subject matter of their thesis.

5 Having received prior approval of the subject matter by the Board of Censors, the candidate must submit a thesis, treatise or paper, in a form suitable for publication, for consideration by the Board of Censors.

Candidates are advised that preference will be given to papers reporting original basic or clinical research work. All clinical research material must be accompanied by documentary evidence of approval by an appropriate Ethics Committee.

Case reports may be acceptable provided they are thoroughly documented, the subject is extensively researched and is then discussed in depth. Reports of a single case will be deemed insufficient.

Review articles may be acceptable only if the review is of the world literature, it is thoroughly analysed and discussed and the subject matter has not received a similar review in recent times.

6 All successful thesis material becomes the property of the Society to be published as it deems fit.

7 The Board of Censors reserves the right to modify any of these requirements from time to time.

MINUTES OF THE EXECUTIVE COMMITTEE MEETING

held in Rabaul on 15/5/94

The meeting opened at 1010.

Present

Drs D Gorman (President), S Paton (Treasurer), C Meehan (Secretary), J Knight (Editor), C Acott and G Williams.

Apologies

Drs A Slark (Past President), D Davies (Education Officer) and J Williamson.

1 Minutes of the previous meeting

Read and accepted as a true record. Proposed by Dr Williams and seconded by Dr Paton.

2 Business arising from the minutes

2.1 Value of face to face meetings, possibly in Cairns in October. It was decided that there was a great benefit in face to face meetings and that the next meeting would in Cairns at the Safe Limits Symposium in October. In following years it would probably be held in Adelaide in November or December when Dr Gorman is in Australia. These meetings would be suitable times for future tenders to be discussed.

2.2 Possibility for an honorarium for Dr Knight if he continues as Editor. This was agreed to in principle. Proposed by Dr Gorman and seconded by Dr Williams. Dr Knight was requested to write a job description. Level of remuneration will then be discussed.

2.3 Extra support needed for the Treasurer and the Secretary. Dr Knight to research the cost of the mail being sorted at central point.

3 Solomons ASM

Dr A A (Fred) Bove be the guest speaker.

4 Treasurer's report

Read by Dr Paton and accepted. Proposed by Dr Acott and seconded by Dr Knight.

5 Correspondence

None received.

6 Other business

6.1 Dr Meehan to contact the New Zealand sub-committee and ask for their minutes and these to be published in the Journal. They are also to be asked to advertise their conferences.

6.2 Discussed future of the presidency and decided to start seeking out future candidates.

MINUTES OF THE EXECUTIVE COMMITTEE TELECONFERENCE

on 31/5/94

The meeting opened at 2030 Eastern Standard Time.

Present

Drs D Gorman (President), A Slark (Past President), S Paton (Treasurer), C Meehan (Secretary), J Knight (Editor), D Davies (Education Officer) C Acott and G Williams.

Apologies

Dr J Williamson.

Business presented at the meeting

This meeting was an extra, urgent, committee teleconference called by the President Dr Gorman to discuss the venue for the 1995 Scientific Conference.

It had been drawn to his notice that the Solomons as a venue had some inherent problems, such as absence of families due to malaria, diving being weather dependent, adequacy of function facilities and expense to the New Zealanders.

After the success of the new dive escort, in Rabaul, the membership had been shown that no single person is essential for a successful meeting. For next year it is essential as a society that we have a very successful meeting run by an alternative supplier to wean the very significant proportion of our membership off the idea that only Allways can provide the vehicle of a successful conference. It was felt that going to an area that was malarial, expensive for the New Zealanders, and where we had been before was setting up any new tenderer for a certain dump. This is the reason why Dr Gorman took up the issue of bringing Fiji forward one year.

It appears that there may be three companies willing to put in tenders at this short notice. It was proposed that on June the 18th the tender for Fiji be sent to every member of the committee simultaneously. The tender document used last year to be used again. That a tender be put together for Mana Island as a yardstick and for another venue as they would suggest. Dr Davies is prepared to convene the meeting at this short notice.

There was some concern expressed by committee members that the society may lose face with the travel diving and medical community with this sudden change in venue after a completed tender.

Decided that in future the committee will discuss tenders at a face to face meeting, this year to be held in October in Cairns, during the Safe Limits Symposium.

In summary, not withstanding the embarrassment at the late change, it is a far lesser evil than having an unsuccessful meeting. The theme and the workshop are to remain the same. The convener is to remain the same. The tendering documentation that the Treasurer produced last time is what we will use this time. The tender documents should be distributed to us all on the 18th June from the College of Anaesthetists. The tenderers are to tender for Mana Island as a yardstick as to what we would consider a minimum requirement, plus whatever else they consider worthwhile.

It was decided that the venue for the 1996 Scientific meeting is to be decided at the committee meeting in Cairns in October.

MINUTES OF THE EXECUTIVE COMMITTEE TELECONFERENCE

on 11/7/94

The meeting opened at 2000 Eastern Standard Time

Present

Drs D Gorman (President), S Paton (Treasurer), C Meehan (Secretary), J Knight (Editor), C Acott, G Williams and J Williamson.

Apologies

Drs A Slark (Past President) and D Davies (Education Officer).

Business

To discuss the new tenders of the 1995 ASM in Fiji.

There were responses from two tenders, AIlways Dive Expeditions and Dive Adventures. They each put in tenders for Mana Island and Castaway Island while Dive Adventures tendered for the Fijian as well.

Dr Gorman and Dr Slark have looked at the tender documents closely and discussed them at length before Dr Slark's departure for England. They feel there only very subtle differences between the two but the free of charge (FOC) issue is a clear difference and that leads them to make a very firm decision.

Dr Davies was held up in theatre and so was unable to join in the meeting. To date he had not been able to make a firm decision as to which particular tenderer to choose.

It was decided that Castaway Island was the venue of choice.

Of the eight committee members who were able to present a vote to the meeting, four were for a change to Dive Adventures and four to stay with Allways. Dr Davies was not able to vote.

Proposed by Dr Gorman, that Dr Davies as convener contact Air Pacific and discuss the exact situation with the FOCs, to start working on a draft of the registration fee breakdown so that a decision on costing can be accurately made, and on that basis to choose the successful tenderer. It was decided that it would be unfair to make Dr Davies to make a casting vote and that if further information showed that the FOC situation does not have the same impact as suspected then Drs Gorman and Slark would have no hesitation in changing their stance.

MINUTES OF THE ANNUAL GENERAL MEETING OF SPUMS

held on 20/5/94
at the Hamamas Hotel, Rabaul, Papua New Guinea

Present

All members attending the Annual Scientific Meeting.

Apologies

Drs David Davies, Harry Oxer, John Williamson, Roger Welch, Peter McCarthy, John McKee and John Finlayson.

The meeting was opened at 1815

1 Minutes of the previous Meeting

The minutes of the previous meeting have been published (SPUMS J 1993; 23 (3): 151). Motion that the minutes be taken as read and are an accurate record: Proposed: Dr Leslie, Seconded Dr George Thomson. Carried.

2 Matters arising from the minutes

None

3 Annual Reports

3.1 President's Report (this page)
3.2 Editor's Report (not printed)

4 Annual Financial Statement and Treasurer's Report (pages 200 to 202)

Accepted. Proposed by Dr Leslie, seconded by Dr Knight. Carried.

5 Subscriptions for the coming year

Recommended to remain the same. Proposed by Dr Paul Langton and seconded by Dr Weaver. Carried

6 Election of office bearers

Nominations had been received as follows:

President	Dr Des Gorman
Secretary	Dr Cathy Meehan
Treasurer	Dr Sue Paton
Editor	Dr John Knight
Education Officer	Dr David Davies
Public Officer	Dr John Knight
Committee Members	Dr Chris Acott
	Dr Guy Williams
	Dr John Williamson

There being no other nominations it was proposed by Dr Leslie and seconded Dr Seppelt that the above be declared elected. Carried.

7 Appointment of Auditor

Mr David Porter is willing to continue as auditor. Reappointment proposed by Dr Paton and seconded by Dr Knight.

8 Business of which notice has been given

8.1 Dr G Leslie moved, and Dr Fred Finlay-Jones seconded, a vote of confidence in Allways for making the travel arrangements for Annual Scientific Meetings. After much discussion Dr J Parker moved that the motion not be voted on. This was carried and no vote was taken on Dr Leslie's motion.

The meeting closed at 1945

PRESIDENT'S REPORT 1994

Once again the Society has had a very successful year, both financially and professionally. This is not to say that the year has been free of controversy.

Journal

The Journal continues to bring great credit to the Society and to the Journal Editor, Dr John Knight. Some letters to the Editor have required significant modification to avoid defamation. Also, in our efforts to "be seen to be fair" and to publish both sides of an argument, some of the papers published in the Journal have not been of the standard now required.

Secretary and Treasurer

Both the Society's Secretary and Treasurer deserve our thanks for their efforts in the last year. Dr Cathy Meehan and Dr Sue Paton are now an effective team and our finances are sound. Similarly, the other members of the committee also warrant our appreciation. During the year, the committee continued to conduct its business by teleconference, with a single face-to-face meeting to interview the tenderers for next year's Annual Scientific Meeting. This frugal practice should be continued.

Australian Medical Association

Perhaps the greatest achievement of the year was the acceptance by the "head-office" of the AMA that there is a need for specific training of those medical practitioners who intend to undertake assessment of candidate's fitness for diving. Again, this achievement owes much to the literary zeal of Dr John Knight.

Diploma of Diving and Hyperbaric Medicine

During the last year, another two medical practitioners, Drs Lindsay Wheen and George Jellinek, were awarded the Society's Diploma. We congratulate them on their achievement.

Recreational Diving Instructor Agencies

Many of the senior members of the Society have been openly critical of the Committee's relationship with the recreational diving instructor agencies. This is unfortunate and denies the considerable benefit that has been derived from the sharing of opinion and data in a noncombative method. This is not to say that the Society will simply echo the opinions of these agencies, but every effort will be made to ensure continuing dialogue.

The issue of technical recreational diving is one where a close liaison between the Society and these agencies will be of mutual benefit.

1995 Annual Scientific Meeting

The 1995 ASM is to be held in the Solomons.* Dr David Davies is to be the convener. The theme of the conference is "Fitness for Diving" and the workshop will be on asthma. The guest speaker will be Dr A.A (Fred) Bove.

Thank you for your time and attention.

Des Gorman
President

* *Shortly after the AGM the venue for the 1995 ASM was changed to Castaway Island Resort, Fiji (see page 198).*

TREASURER'S REPORT 1994

The audited Statement of Receipts and Payments for the 12 months ended 31 December 1993 show the continuing healthy financial state of the Society. This is due to the combined effect of the increase in membership fees in June 1992 and dramatic cost reductions including the termination of the contracted secretarial service.

As a result, the Society's operation relies on a considerable amount of voluntary work by the Editor, Secretary and Treasurer. This situation is unlikely to be sustainable in the long term. It is envisaged that in the near future assistance with the workload of these office bearers will become essential and costs increase correspondingly. So although with our present financial reserves any adjustment of membership fees for the 1995 subscription seems unnecessary an increase for 1996 subscriptions is anticipated.

In comparing this year's accounts with those of the immediately preceding year several points must considered:

1 The 1993 accounts cover a 12 month period and those of 1992 only cover 8 months because of the change in annual accounts to reflect calendar years as do annual subscriptions and the journal volumes.

2 Subscriptions were levied in July 1992 for an 18 month period ending in December 1993. Hence the lower level of subscriptions collected in 1993.

3 In 1993 secretarial costs directly relating to the production of the journal have been included in the journal costs. If secretarial costs were apportioned as in 1992, the figure would have been $3,100, still a substantial reduction. The purchase of a scanner for the Editor's computer at a cost of $1,925 reduced the Editor's secretarial costs by fifty percent. However costs for the current 12 months are anticipated to rise because of the additional workload of levying subscriptions from the entire membership.

4 For the same reason stationery costs will rise. And yet another change in the Society's address (occasioned by the move of the Australian and New Zealand College of Anaesthetists) will mean reprinting all our stationery again!

5 Travel, Phone and Conferences appears falsely elevated because it includes payment of the beverages for the gala dinner at the 1993 scientific conference in Palau, funded by the $5,000 received in sponsorship from SAAB.

Continued on page 202

SOUTH PACIFIC UNDERWATER MEDICINE SOCIETY
STATEMENT OF RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31 DECEMBER 1993

		12 Months ended 31/12/93	**8 months ended 31/12/92**
OPENING BALLNCE			
ANZ Bank	- Access A/c	6,131	136
	- Cash management A/c	1,017	20
	- ANZ V2 PLUS	37,107	-
		44,255	156
INCOME			
Subscriptions		32,626	76,161
Interest		2,036	241
Advertising and journal sales		2,506	1,443
Sponsorship - SAAB		5,000	-
		42,168	77,845
		$ 86,423	$ 78,001
EXPENDITURE			
Advertising		-	565
Secretarial		1,451	6,838
Stationery		709	889
Journal		19,428	10,229
Postage and facsimile		3,131	1,945
Travel, telephone and conferences		7,817	827
Equipment, see note		5,913	5,360
Miscellaneous		473	457
Bank charges		710	760
Audit		350	500
North American Chapter costs		2,997	2,876
Loan repaid		-	2,500
		42,979	33,746
CLOSING BALANCES			
ANZ Bank	- Access A/c	945	6,131
	- Cash management A/c	-	1,017
	- ANZ V2 PLUS	42,499	37,107
		43,444	44,255
		$ 86,423	$ 78,001

NOTE: Equipment is written off as purchased.

These are the accounts referred to in the report of D S Porter, Chartered Accountant, Newport Beach, New South Wales 2106, dated 3/5/94.

AUDITOR'S REPORT

I have conducted various tests and checks as I believe are necessary considering the size and nature of the society and having so examined the books and records of The South Pacific Underwater Medicine Society for the year ended 31st December 1993. I report that the accompanying Statement of Receipts and Payments has been properly drawn up for the records of the Society and gives a true and fair view of the financial activities for the period then ended.

3rd May 1994
David S Porter, FCA, Chartered Accountant

6 Equipment comprises the scanner, a new Macintosh Computer for the Editor and software.

7 North American Chapter costs mainly relate to mailing the journal within the USA after bulk airfreighting from Australia. This is done by Steve Dent, secretary of the American Chapter. As a result of this service our North American members receive their journal about a month after publication. Please note that a balance of US$1,000 is kept in the account of the North American Chapter to avoid bank charges.

On a completely different note I must draw to your attention that although 1994 annual subscription renewals were sent out in January, reminders have had to be sent to 715 members whose renewal payments had not been returned by the third week in April ! This represents a considerable additional expense in time and money.

Total membership (inclusive of those not yet renewed for 1994) is 1283 divided between:

Australia	913
New Zealand	140
North America	140
Other Countries	90

Sue Paton
Treasurer

NEW ZEALAND CHAPTER OF SPUMS

MINUTES OF THE 1994 ANNUAL GENERAL MEETING

held at 2000 on 19/3/94 at the Chatswood Manor Inn, Whakatane.

Present

Dr Andy Veale (Chairman of the Chapter) and nine members.

Chairman's report

Presented and accepted (Moved Mike Davis, seconded Martin Rees). The Chairman expressed the desire to stand down.

Treasurer's report

Presented and accepted. The Treasurer reported that the accounts had not been audited as the Chapter is not a Society Incorporated in New Zealand and the financial transactions involved hardly warranted the cost. The Treasure also announced that he had, on the advice of his accountant, deregistered the Chapter's GST registration, as SPUMS (NZ), with Inland Revenue. The reasons being SPUMS' minuscule income coupled with the lack of provision of services or goods to members. Conference expenses of members are, of course, tax deductible.

Election of Office bearers

Dr Mike Davis of Christchurch was elected unopposed as Chairman.

There being no willing candidate offering Dr Rees Jones of Whangarei volunteered to continue in the position of Secretary/Treasurer for the next year, giving notice that it will most certainly be his last in the position.

As Andy Veale literally departed the meeting the Dr M Davis, the new Chairman of the Chapter, took the chair.

Future Meetings

Tentative venues for the future scientific meetings of the New Zealand Chapter of SPUMS were decided after free ranging discussion.

1995 Whitanga or Tairua
Theme: Fitness for diving including Asthma and Diving. Organisers: Dave Pemberton and Chris Morgan.

1996 Christchurch
Pre- or post- Dive Conference. Fiordland or Kaikoura. Organiser: Mike Davis.

1997 Tutukaka. Organiser: Rees Jones.

Meetings will be held approximately late March so that workshop topics for the SPUMS ASM can be discussed and a New Zealand view forwarded. NZ members to be polled for views on venues, e.g. should we go offshore to say Fiji, and preferences for duration and times, e.g. long weekend, ordinary weekend plus Friday and/or Monday.

General business

The retiring Chairman, Andy Veale, tabled the report on possible future directions for the Chapter. After some initial discussion, the meeting decided that because of the lateness of the hour, the importance of the topic and the small number of members present that full discussion on the subject be deferred until the next AGM.

A list of loan books available from the SPUMS library was included as a supplement to Andy Veale's report. Des Gorman said that loan copies of Bennett and Elliott were available. Mike Davis stated that he has willed his personal collection of underwater medicine and diving history books to the SPUMS library.

Concern was expressed at the lack of knowledge of SPUMS among the general medical community. Some GPs with no knowledge of, or training in, underwater medicine were still doing Fitness to Dive examinations very inadequately. The Secretary was instructed to insert an advertisement for SPUMS in NZ Doctor, publicising the Society.

Concern was expressed at the lack of accurate information on diving accidents. The Secretary was instructed to write to the ACC and the Water Safety Council to request that updated statistics be provided to SPUMS as a matter of course.

The meeting closed at 2100.

NEW ZEALAND CHAPTER NEWS

The 1994 New Zealand Chapter Annual Scientific and General Meeting was held at Whakatane over 18th-20th March. This was an extremely enjoyable and well-organised weekend meeting. NZ members who attended are indebted to Drs Dave Pemberton (and Rosie !) and Chris Morgan for their excellent work - thank you.

Dr Mike Davis described some of the anatomical and physiological adaptations to breath-hold diving shown by the diving mammals. By comparison, man shows very little evidence of adaptive mechanisms to breath-hold diving. Diving prowess in humans is largely dependent on having unusually large lungs for a given body mass, enhancing oxygen stores and thus dive time. There is no evidence in man of the metabolic switch to anaerobic metabolism which is a vital component of the diving reflex in the deep diving mammals. The mechanisms of hypoxic loss of consciousness in breath-hold diving were described, emphasising the central importance of the non-linearity of the oxygenhaemoglobin dissociation curve. Finally, some of the clinical problems that may present in underwater hockey players were reviewed.

Dr Andy Veale discussed the mechanisms of lung injury in pulmonary barotrauma, outlining current hypotheses to explain why vascular gas embolism occurs predominantly in some situations and emphysema and/or pneumothorax in others.

He then presented some controversial ideas on respiratory fitness for diving that he plans to elaborate at the SPUMS Annual Scientific Meeting (ASM) at Castaway Island, Fiji, in 1995. There are two ways to approach the medical examination of the intending diver. Prescriptive standards, eg. lists of absolute and relative contraindications, combined with “pass or fail” standards is one. The other is to use discretionary standards, where the task of the doctor is to undertake the assessment and explanation of risks. This then allows the diver and training organisation to make informed decisions on risk acceptance. The latter type of medical requires that the doctor concerned must have postgraduate training in diving medicine. He went on to discuss how a discretionary approach might be applied to respiratory fitness, and highlighted the relative paucity of hard data on the actual risks for diving associated with respiratory disease.

Dr Rees Jones’ talk on the pathology of diving accidents was illustrated using case studies and a very fine and comprehensive set of slides outlining the gross and histopathological findings in various situations. There was a wealth of visual material to absorb during an engrossing hour.

Dr Des Gorman as usual packed enough into his talk to keep the audience occupied for the entire weekend let alone a brief hour. He reviewed some of the current research being carried out at the Royal Adelaide Hospital, the RNZ Naval Hospital in Auckland and elsewhere. Of particular interest were the ongoing study on heliox therapy for DCI and the recent discovery of the natural role of carbon monoxide as a neurotransmitter. He also summarised the current data on the long term sequelae of diving and conducted a question and answer session with the audience which the chairman was hard-pressed to bring to an end.

The meeting was pleased to have Rex Gilbert from the New Zealand Underwater Association (NZUA) talking about aspects of sport diving of mutual interest to NZUA and SPUMS. Rex is the NZUA Accident Recorder, and he outlined some of the difficulties of the job. Chris Heron provided our post-prandial entertainment in lightheartedly drawing parallels between endoscopic surgery and scuba diving. The audience was assured that he was a better surgeon than he was an underwater photographer!

OBITUARY

Stephen John (Jim) Lloyd
1923-1994

Surgeon Rear Admiral Lloyd AO RAN (retired) died suddenly in hospital on 15/9/94. Jim was well known to those members and associates who attended Annual Scientific Meetings during the last 10 years.

Jim served in India in Scottish regiment, the Cameronians, during World War 2 (hence his kilt). He studied medicine at Bristol University and graduated in 1951. He joined the RAN in 1952 after a year as an anaesthetic registrar. An asthmatic, he sensibly never learned to dive, but as a medical officer of the RAN he understood the medical problems of the divers under his care. His service with the Fleet Air Arm led to expertise in Aviation Medicine and for many years he was the only service medical officer with training in the effects and treatments for Nuclear, Biological and Chemical Warfare. His naval career was crowned by his appointment as Director General of Naval Health Services and Surgeon Rear Admiral in 1976. He oversaw the transfer of the

RAN medical service from Victoria Barracks to Canberra in 1978. When he retired in 1981 he had brought in many sensible changes to the naval medical system. In retirement he became the Medical Officer for the ACT police diving team.

I have known Jim since the 1960s and always found him a true friend. We shared a similar background of naval service. I knew something of bee keeping, but nothing of his other hobby of ham radio. Living in different cities we did not meet often but I have always enjoyed our meetings and have many happy memories of convivial evenings as well as working with “Noisy”. He was quiet and reserved, hence his nickname. I, his family and his many friends will miss him.

John Knight

SPUMS POLICY ON COMPUTER ASSISTED DIVING

Dive computer design

1 The risk of decompression illness associated with the algorithms and logic used in the current generation of dive computers has not been established. This unknown risk must be clearly understood by potential users of dive computers. The Society consequently supports the DAN decompression illness study.

2 A standard display format for dive computers should be developed and is strongly recommended by the Society.

3 Recommended features in a dive computer include audible and visual alarms (eg. maximum ascent rate violations, low cylinder air pressures), legible fonts, a capability to be “downloaded” and to be compatible with the DAN database, and automatic activation upon compression, without the need to be turned on manually.

4 Desirable features in a dive computer include dependent and independent penalty systems (ie. a systematic “fudge” system that calculates increasingly conservative decompressions in the presence of determined adverse factors), graphic and numeric displays and, in those with residual air calculations, an allowance for “safety stops”.

Training to use dive computers

1 Basic diving courses must include instruction in computer assisted diving and the procedures to adopt in the event of a dive computer failure.

2 Where practical, sale of a dive computer should be accompanied by instruction from the retailer, or their agent, in the use of the specific apparatus. Manufacturers have a responsibility to produce comprehensive instruction manuals. Divers about to use a dive computer should read and understand these instructions beforehand.

Diving practice with a dive computer

l Dive planning must take priority in all diving, including computer assisted diving. The computer assisted diving practice must conform to the conventional model of “safe” diving. This means only one dive/day beyond 30 m, repetitive dives should be progressively shallower, no recreational dive should require staged decompression, ascent rates should not exceed 20 m/min, a “safety stop” should be performed after all dives if possible, divers should maintain good hydration before and after dives, and in accordance with the current DAN recommendations, a diver should have a rest day after any 3 consecutive days of diving. These diving practices should be included in the dive computer manufacturer’s instruction manual.

2 Sole reliance on a dive computer cannot be recommended and divers should always have an alternative method of measuring depth and time.

3 The use of a dive computer’s output must be limited to the actual wearer of the dive computer.

4 Any problem or incident involving a dive computer should be reported on a Diving Incident Monitoring Study form.

LETTERS TO THE EDITOR

CLOSURE OF NEW ZEALAND CHAMBER

P.O.Box 35, Tai Tapu
New Zealand
28/9/94

Dear Editor,

SPUMS members should know that the operations of the recompression chamber in Christchurch, New Zealand, have ceased, either temporarily or permanently, on safety grounds. It is to be hoped that the service will recommence some time in the next few months, if the chamber is transferred to Christchurch Hospital and the facilities upgraded to meet modern standards.

However, this is by no means certain since Dr Alistair Gibson and I have been battling to achieve this for over four years without the various administrations that we have had to deal with in that time reaching any firm decisions. Recognition of the merits of this clinical service has been very difficult to achieve despite a wealth of data demonstrating its cost-effectiveness.

All enquiries regarding diving emergencies in New Zealand should now be addressed to the RNZN Hospital, Devonport, Auckland (09) 445 5922 or the Diver Emergency Service (NZ) (09) 445 8454

Michael Davis

DIVING AFTER ROUND WINDOW RUPTURE AND REPAIR

Suite 2, Gallagher House
37 Gordon Street
Mackay, Queensland 4740
25/10/94

Dear Editor,

I read with interest the letter entitled *Diving after round window rupture and repair* and the editorial response. It is of interest that this diver ruptured his round window during snorkel diving, which commonly produces this injury.

Whilst the reply is sound and logical, otologists will categorically state that one should never dive again following such injury and repair. To my knowledge there are no formal studies to substantiate this advice. However I understand that a pearl diver returned to diving after repair, ruptured his window again and nearly drowned due to the disorientation. I have seen a stapedectomised patient who was rendered profoundly deaf by barotrauma on a commercial flight. While in theory the repair of a round window rupture should be stronger than that following stapedectomy, the pressures involved in diving are considerably greater.

To my knowledge the senior naval ear, nose and throat doctors will absolutely ban further diving and I have no doubt they would categorically make this point if required to in a court of law. In the circumstances any diving doctor who does not comply with this view is taking a grave chance if medico-legal action arises because of their less than clear and forceful advice that divers with this injury should never dive again.

John Robinson
(ENT Surgeon)

BLACKOUTS AND DIVING

170A Richardson Rd
Mt Albert, Auckland 4
3/10/94

Dear Editor,

Recently I was consulted by a prospective diver who had been certified “fit to dive” by a colleague. However, the instructor was a little worried by the medical history, and sent him off for a second opinion.

For the last twenty years or so, about twice a year this man has had “blackouts” while he was awake. They occur without warning. He is unconsciousness for perhaps 30 seconds or a minute and is disoriented for a period afterward. I dissuaded the chap from diving, believing he had a total contraindication to recreational scuba diving.

However, this man’s risk of dying underwater may be acceptable. Assuming he is awake 5,000 hours a year, has two “blackouts” a year and dives last half an hour each, then he has about 1 chance in 5,000 of blacking out during any one dive. If his diving career lasts 30 dives (probably above the average for a recreational diver), his risk of a blackout during at least one of those dives is $1-(0.9998)^{30}$, or 0.006. If his career lasts 50 dives there is a 1% chance he will blackout underwater during at least one of those dives. If it lasts 100 dives, there is a 2% chance.

This man drives a car. It seems irrational to prohibit him from recreational scuba diving (as I did), while he continues to indulge in a far more risky activity, considering the hours per year he spends behind a wheel, compared to those he would spend underwater. Any thoughts?

Rhys Cullen

PATENT FORAMEN OVALE

Operating Theatre Laboratory
Austin Hospital
Heidelberg, Victoria 3084
Australia
27/10/94

Dear Editor,

Nowadays many hospitals are using transcranial doppler equipment during carotid endarterectomy to demonstrate air or debris emboli.

I have recently had my transcranial Doppler performed at the Austin Hospital during a forced Valsalva manoeuvre and injection of well shaken saline solution and the results were negative. In view of the increased awareness of the potential for diving injuries secondary to paradoxical air embolus through a patent foramen ovale (PFO) this technique could perhaps be listed as one increasingly available technique of detecting patent foramen ovale. Perhaps it could be used to establish whether in fact PFO is as common as a number of recent papers have indicated.

Mark J. Sullivan

BOOK REVIEWS

The DSAT Recreational Dive Planner. Development and validation of no-stop decompression procedures for recreational diving.
RW Hamilton, Raymond E Rogers, Michael R Powell and Richard D Vann.
Diving Science and Technology Corporation and Hamilton Research Limited. 1994
Available from PADI at no charge.

The PADI Wheel and Recreational Dive Planner (RDP) are based on Haldanian decompression theories with the 60 minute half time controlling repetitive diving and allow multi-level dives. This book discusses the development of this decompression table and its testing.

The perceived inadequacy of the USN tables for recreational diving provided the impetus for the development of the RDP. Unfortunately the idea that uptake and elimination of gas are mirror images survived into the RDP when this has long been known to be untrue, but it does simplify the mathematics.

Basic facts about decompression sickness and bubble detection, statistics and testing are covered before coming to the story of the development of the RDP. The mechanics of constructing a Haldane based table are discussed and the methods by which the various values used in the RDP table were arrived at. This discussion should be read by all intelligent divers for it shows how arbitrary the figures are, being based on mathematical models rather than the (unknown) physiological facts. The reader is taken through the ideas that govern the RDP repetitive dives and multi-level diving and The Wheel.

Most of the book is devoted to the test programs, conclusions and references. The first test program, testing single day multi-level and repetitive dives, included chamber runs and open water diving in Puget Sound where the water is very cold. Most of the latter dives were terminated when the diver became cold well before the time allowed by the table. All 911 dives, whether in the chamber or at sea, were monitored for venous bubbles. These were found in 10 to 12% of the divers almost all of which were the harmless grades 1 and 2.

One set of chamber trials of 6 multiple dives over six days was abandoned after a diver developed mild decompression sickness (DCS). There were 54 dives in this series. The test program was then reduced to four dives a day for six days, to simulate an overseas diving holiday. Twenty divers did 475 dives, all Doppler monitored. There were no cases of DCS but some subjects were fatigued and 7 had grade 3 bubbles at some time

There is a very fair discussion and analysis of results which point out the difficulties of amassing enough dives to make accurate statistical predictions. In all, the authors of this book consider that the testing validated “a new mode of decompression management for recreational diving”. Apparently twice as many individual dives were used to validate the RDP as were used for the DCIEM tables. Even so 8 of the profiles for repetitive dives were tested on less than 10 dives. But DSAT, which is a subsidiary of PADI, is to be congratulated on its efforts at testing. Maybe the numbers are inadequate, but most of the schedules tested were stressful, being to the RPD limits. In the reviewer’s opinion the exactness of figures in a table are less important in avoiding DCS than the way the diver dives. Many make little effort to dive a sensible plan or to stay at the planned depth or watch their air consumption or time underwater. However good the table, these people will put themselves at risk.

Anyone who is interested in decompression theory and table testing should write to PADI for a copy of this book and hope that the stock is not exhausted.

John Knight

INTERCEPTED LETTERS

P.O.Box 268
Newport Beach
New South Wales 2106
7/12/93

Dear Bob and Dinah

I greatly enjoy your newsletter, and find myself entirely in agreement with all of your musings concerning diving equipment, diving safety, diver training, diving legislation etc.

In the 1950s as an old self-taught diver of some two years standing in the Bahamas, whose sole diving experience was in solo mode, I was amazed to learn about buddy breathing when David Brazier arrived in Nassau and started the Underwater Club. I took David to several dive spots I had found (usually by puttering around in my eight-footer and hopping over the side with the anchor rope, minus the anchor needless to say, tied to my weight belt. I figured I could not lose the boat that way if I got too immersed, so to speak, in what I was doing).

But back to buddy breathing. I first dived with a US Navy twin hose rig of venerable age. More than a year after I had first used it, I realised that my exhaling problems were caused by a partly fused flap valve, and it took me some time after that to train myself to exhale without violent physical effort. No gauges of course, so I used to come up when the inspiratory effort equalled the expiratory. A tank of air didn't last awfully long.

Having felt that an almost-out-of-air ascent was the norm, I resolved, on hearing of buddy breathing and being horrified by its implications, that, if my diving partner ran out of air, I would take off my rig and let him (or her) come up with it, while I ascended in my normal manner. In those days we rarely went below 30 to 50 feet (9 to 15 m).

It appears that the dreaded buddy breathing is difficult to dispose of, although the cumbersome octopus option has obvious advantages, albeit great expense and one more thing to go wrong.

You wrote a couple of years ago in the SPUMS Journal about mental fitness for divers, and asked for some suggestions from the doctors. I don't know if you received any replies, but your query reminded me of a similar point I made in lectures to doctors in the Bahamas sometime in the late 60s or early 70s.

Imagine my surprise last week when I was going through some old medical bumf and I found the same handwritten lecture ! Let me share the relevant section with you, verbatim.

"The only other condition or set of conditions that one may wish to add to this list would be a most important one, which, however, is virtually impossible for a physician to asses if he sees the prospective diver for the first time during the pre-diving physical. That is mental illness.

Diving is fun (Sorry, Bob !), but it is also an activity which is carried on in a totally strange medium, and the diver's life or that of his companion, may depend on his reactions to emergency situations which may arise. I certainly would not like to have a mental defective, a psychopath, a paranoid schizophrenic, a suicidal depressive or a homicidal maniac as a diving buddy, and these persons should certainly be discouraged from under-water activity. They are not well adjusted in air, and, although I have no experience in underwater psychiatry, I would assume that their contact with reality may be lost even further in the submarine environment.

Perhaps, of course, the reverse is true; but, until we see mental hospital inmates officially being given twice or thrice daily submersive treatments, I prefer to class mental defect or illness, past or present, as a contraindication."

This begs the question, of course, as to how to diagnose it. I feel the same way about psychiatrists as you feel about diving legislators, and we all know how the phrase "of unsound mind" can be argued ad nauseam by the best of 'em.

Mental illness, like mental attitude or state, cannot be predicted or even diagnosed definitively on one examination in the individual case. All that can be given is a probability factor. How's that as a definitive statement from a non-, even anti-, psychiatrist ?

I haven't been diving for a couple of years now. It all seems to have become too organised, to overburdened, too expensive, too repetitive, too equipment orientated. Oh for the double hose tank (preferably with a fully functional valve), no gauges, a horse-collar BC (the first I used, by the way, was a surplus Pan-Am aeroplane safety vest), a deserted reef and no buddy !

With appropriate modifications, you provide this, and, after the Telita experience, nothing else seems really worth it. Good on you, Bob and Dinah.

Anyway, folks, keep up the good work, keep plugging away at legislative incongruities and long may Telita and Tiata continue to provide superb diving how it was meant to be.

Grahame Barry

SPUMS WORKSHOP ON COMPUTER ASSISTED DIVING

THE DEVELOPMENT OF SPUMS POLICY ON COMPUTER ASSISTED DIVING

Des Gorman, Chris Acott and Drew Richardson

Introduction

The SPUMS workshop on computers and diving was conducted at the 1994 Annual Scientific Meeting of the Society in Rabaul, Papua New Guinea. As with the Society's previous workshop on emergency ascent training, the outstanding feature of this exercise was the degree of consensus. Indeed, it was a pleasure to be able to debate issues in diving safety without the acrimony and personal attacks that usually accompany any consideration of recreational diving practice. The latter is, unfortunately, especially true if equipment (and hence commerce) is involved. Again, the commitment of PADI to the workshop was greatly appreciated; it is noteworthy that the 1994 workshop was improved over that of 1993 by the presence of both John Lippmann and Paul Lunn who were able to represent the views of NASDS Australia.

The presentations

All but one of the presentations is published in this edition of the Journal. A review of the kinetics of inert gases in diving presented by Des Gorman is to be published in "Anaesthesia and Intensive Care"so is not available until after publication. Included are personal reports of diving with computers by David Davies and Guy Williams, accounts of current and future diving computer design by John Lippmann, a review of computer assisted diving by Drew Richardson, analyses of diving incident monitoring data by Chris Acott and a pro and con discussion by John Knight. Those from Ray Rogers and Bruce Wienke were not presented at the workshop.

General observations

The workshop accepted at the outset that the use of a diver-carried apparatus that measures depth and time and (from these inputs) calculates decompression requirements (a decompression or dive computer) is not a "passing fad" and will be a feature of recreational diving (and some forms of military and commercial diving) for the foreseeable future. Consequently, the workshop resolved that the Society should establish clear and practical advice for dive computer use and development. The need to establish safe diving practice for divers using dive computers (see comments below) convinced the workshop that the title of both the debate and subsequent policy should be "computer assisted diving".

Despite this acceptance, it is clear that the plethora of data presented to support diving with a dive computer is essentially anecdotal. There are limited objective data for any type of diving exposure and outcome, and these observations are largely limited to square profile diving and not to the multi-level type of diving computation that is intrinsic to diving with a dive computer. It follows that the risks of diving with a dive computer have not been established to any degree of statistical validity. Indeed, the Diving Incident Monitoring Study (DIMS) data suggest that diving with a dive computer may have the same associated risk of decompression illness (DCI) as diving without any form of decompression schedule. Given the reasonable assumption that the extent of the dive is to some degree related to outcome, it is self-evident that a shift from square profile diving logic, in the calculation of the decompression requirement but not in the actual dive, to not only multi-level diving, but also multi-level logic in calculating decompression will often increase the available time for divers underwater and hence the risk of DCI. Extraordinarily, this feature of dive computers, the increased exposure while not mentioning the increased risk, is used as a major selling feature. This criticism of the shift from square profile to multi-level profile logic is not a criticism of dive computers per se, but rather a criticism of one way in which the current generation of dive computers can be used. It follows that any potential buyer of a dive computer must be aware of the following:

a the risk of decompression illness associated with use of the current generation of dive computers has not been established (Divers Alert Network (DAN) data show a steady annual increase in the percentage of DCI that occurs in computer users, however, it is difficult to assess the significance of this without knowing both the percentage and the overall nature of computer assisted dives);

b for a given decompression algorithm and a multi-level dive, calculation of the decompression requirement using a multi-level logic will have a greater associated risk of decompression illness than the equivalent calculation using a square profile logic (see comments about DAN data above);

c the current "safety" of recreational diving has been established by conservative decompression practice and this is threatened by non-selective use of dive computers (see below with respect to the comments about safe diving).

In the context of collecting objective data of the risks associated with recreational diving, there was widespread support for the DAN research project to record the outcome of one million dive computer-monitored dives.

Consequently, it was agreed that a dive computer should be both "down-loadable" and compatible with the DAN database.

It is clearly possible to use a dive computer for multi-level diving in such a fashion that the consequent accumulated exposure constitutes a very high risk for decompression illness. The Workshop was unanimous in support of the need to impose "safe" diving practice on computer assisted divers, e.g. dive planning must have priority, only one dive/day to any depth beyond 30 msw etc. see page 204 for the actual Society policy.

There was considerable discussion on the features that a DCC should have and agreed essential features are included in the policy. There was some disagreement on whether there should be a standard format for information display (analogous to that being introduced for anaesthesia equipment). Despite objections that this would constrain developers of dive computers, it was agreed by a large majority that a common display format (ie. specific information, such as elapsed time, would appear in the same "place" in the dive computer display) was needed to improve the reliability of dive computer use/review by novice divers, divers who have recently purchased a dive computer and dive buddies.

Of major concern was the report that 30% of surveyed divers who used a dive computer had experienced a dive computer failure during a dive. Even allowing for improvements in dive computer design since these data were collected, it is clear that sole reliance on a dive computer can not be advocated and that divers must have access to abort procedures. This again underlines the need for dive planning.

The issue of training was raised in the specific context of: the recreational instructor agencies and general training; the obligations of a retailer of dive computers to purchasers of dive computers; and the obligations of purchasers themselves. Consensus statements were possible and these are included in the policy.

Des Gorman, who chaired the Computer Assisted Diving Workshop, is Director of Medical Services of the Royal New Zealand Navy and the President of SPUMS. His address is RNZN Hospital, Naval Base, Auckland 9, New Zealand.

Dr Chris Acott is the Co-ordinator of the Diving Accident Monitoring Study. His address is the Hyperbaric Medicine Unit, Department of Anaesthesia and Intensive Care, Royal Adelaide Hospital, North Terrace, Adelaide, South Australia.

Drew Richardson is Vice-President, Training, Education and Memberships, PADI International Inc., 1251 East Dyer Road, Suite 100, Santa Ana, California 92705-5605, U.S.A

UNDERSTANDING DIVE TABLE AND METER PROCEDURES

Bruce Wienke

Diving model

Decompression sickness results from excessive changes in ambient pressure over a particular period of time. With simple decompression sickness, bubbles, or some related form of free gas phase, are thought to trigger a complex chain of physico-chemical reactions in the body, affecting the pulmonary, neurological, and circulatory systems adversely. Many factors are relevant to the formation of bubbles, such as gas uptake and elimination in the tissues and blood, gas solubility and diffusivity, tissue vascularity and type, breathing mixture, amount of pressure reduction, temperature, presence of preformed nuclei, and individual susceptibility. To prevent decompression sickness, appropriate diving measures limiting depth, time, and repetitions form the basis of diving tables and schedules, more recently encoded into digital underwater computers.

History

Tables and schedules for diving at sea level can be traced to a model proposed in 1908 by the eminent English physiologist, John Scott Haldane.[1] He observed that goats, saturated to depths of 165 feet of sea water (fsw), did not develop decompression sickness if subsequent decompression was limited limited to half the ambient pressure. Extrapolating to humans, researchers reckoned that tissues tolerate elevated dissolved gas pressures (tensions), greater than ambient by factors of two, before the onset of symptoms. Haldane then constructed schedules which limited the critical supersaturation ratio to two in hypothetical tissue compartments. Tissue compartments were characterized by their halftime, τ, that is, the time required for the compartment to halve (loose) or double (gain) dissolved nitrogen. Halftime is also termed halflife generically for exponential (decay) processes. Five compartments (5, 10, 20, 40 and 75 minutes) were employed in decompression calculations and staged procedures for fifty years.

Some years later, in performing deep diving and expanding existing table ranges in the 1930s, Hawkins and Shilling,[2] and Yarborough[3] assigned separate limiting tensions (M-value) to each tissue compartment. Later in the 1950s and early 1960s, Dwyer,[4] Des Granges [5] and Workman,[6] in addressing repetitive exposures for the first time, advocated the use of six tissues (5, 10, 20, 40, 80 and 120 minutes) in constructing decompression schedules, with each tissue compartment again possessing its own limiting tension. Temporal uptake and elimination of inert gas was based on mechanics addressing only the macroscopic aspects of gas exchange between blood and tissue. Exact bubble production mechanisms, interplay of free and dissolved gas phases, and related transport phenomena were not quantified, since they were neither known nor understood. Today, we know much more about dissolved and free phase dynamics, bubbles, and transport mechanisms, but still rely heavily on the Haldane model. Inertia and simplicity tend to sustain its popularity and use, and it has been a workhorse.

Dissolved Gas Exchange

Dissolved gas models limit degrees of tissue supersaturation, assuming gas exchange is controlled by perfusion (blood flow rate) or gaseous diffusion in blood-tissue media. Exchange of inert gas is driven by the local gradient, that is, the difference between the arterial blood and local tissue tension. Obviously the exchange process is very complicated, and models are only approximate. The dissolved gas model emerged early in the Haldane studies of decompression and dominated models for many years, as charted by Behnke,[7] Hempleman,[8] Bühlmann,[9] Crocker,[10] and Workman.[6] Recent application and twists on the Haldane model can be seen in studies by Nishi,[11] Thalmann,[12] Spencer,[13] Weathersby[14] and others.

Perfusion limited gas exchange is modeled in time by mathematical classes of exponential response functions, bounded by arterial and initial tissue tensions. Compartments with 2, 5, 10, 20, 40, 80, 120, 240, 360, and 480 minute halftimes, τ, are employed in applications today, and halftimes are assumed to be independent of pressure. A one-to-one correspondence between compartments and specific anatomical entities is neither established nor implied. For large values of τ, tissue uptake and elimination of inert gas is relatively slow according to the response function. For small values of τ, inert gas uptake and elimination proceed much more rapidly. According to Kety,[15] the major controlling factor is the blood flow rate, $1/\tau$ effectively. Actually, gas uptake and elimination in all tissues is not controlled just by perfusion. Diffusion may dominate in certain tissue types, regions with lesser vascularity and greater distance between capillaries, such as bone and spinal cord. In others, both perfusion and diffusion are rate limiting.

The rate of uptake and elimination of inert gas is symmetrical when the same set of tissue halftimes are employed in calculations. However, this is not always the case. Microbubbles in the circulatory system, particularly venous gas emboli, render gas uptake and elimination asymmetrical. Bubbles in the interstitial areas, or agglutination of red blood cells in reaction to foreign bubbles would have similar effect on local perfusion rates. In such instances, halftimes for uptake are then theoretically shorter than halftimes for elimination.

Critical Tensions

Haldane theory limits degrees of dissolved gas buildup, hypothetically absolute compartment supersaturation, by critical values, M, having a modern range, $122 \leq M \leq 36$ fsw, notably of American origin. Equivalently, critical ratios, R, and critical gradients, G are also employed, with the $R = M/P$ and $G = M - P$, for P, ambient pressure. Critical parameters evolved from self consistent application of assumed tissue response to sets of exposure data, that is, trial and error bootstrapping of model equations to observed exposure time limits. Newer compilations ultimately extend older ones in like manner.

At depth the critical tension is the sum of M_0 and ΔMd, that is, $M = M_0 + \Delta Md$. Such parameters form the basis for most tables and meter algorithms, with a noted recent tendency to reduce critical tensions and (consequenfly) no-stop time limits for safety.

Validation is central to diving, and significant testing of no-stop and saturation diving schedules has transpired. In between, repetitive (more than one dive in a 12 hour period), multi-level (arbitrary depths throughout the course of a single dive), deeper-than-previous (second repetitive dive deeper than first), and multi-day (repetitive dives over days) diving cannot claim the same benefits, though some ongoing programs are breaking new ground. Application of (just) dissolved gas models in latter cases possibly has witnessed slightly higher decompression sickness incidence than in the former ones, as discussed in newsletters, workshops, and technical forums. Some hyperbaric specialists also suggest higher incidence of rash (skin bends) under repetitive loading. While statistics are not yet conclusive, they raise some concerns theoretically addressed by considering both dissolved and free phase gas buildup and elimination in broader based bubble models. Such models often focus on the amount of free phase precipitated by compression-decompression, and contain dissolved gas models as subset. In limiting the volume of free phase in time, they must also limit the growth rate.

Tables and meters

Operational diving requires arbitrary numbers of dives to various depths over periods of hours, and often days. Once a standard set of decompression tables has been constructed, with bounce diving the simple case of no-stop decompression, a repetitive dive procedure is a necessity. After any air dive, variable amounts of dissolved and free residual nitrogen remain in body tissues for periods of 24 hours, and more. Similarly, elevated tissue tensions can promote, or sustain, bubble growth over the same time scales. This residual gas buildup (dissolved and free) will shorten the exposure time for subsequent repetitive dives. The longer and deeper the first dive, the greater the amount of residual tissue nitrogen affecting decompression on subsequent dives. No-stop depth-time allowances for repetitive dives are reduced in such circumstance. Within bubble models, residual free gas phases are also included in procedures, imposing additional constraints on repetitive diving. The many possibilities are easily tracked in continuous time mode by computers, as mentioned, but tables face a more difficult task.

Tables

Considering only dissolved gases, one standard table approach groups combinations of depth and exposure times according to the surfacing tension in the slowest compartment. Then it is possible to account for desaturation during any arbitrary surface interval. The remaining excess nitrogen at the start of the next dive can always be converted into equivalent time spent at the deepest point of the dive. So called penalty time is then added to actual dive time to update appropriate tissue tensions. Surfacing tensions in excess of 33 fsw (absolute) in the slowest compartment are assigned letter designations (groups), A to O, for each 2 fsw over 33 fsw. Any, and all, exposures can be treated in this manner. To credit outgassing, a Surface Interval Table, accounting for 2 fsw incremental drops in tensions in the slowest compartment, is also constructed. Such procedures are bases for the US Navy Air Decompression and Repetitive Surface Interval Tables, with the 120 minute compartment (the slowest) controlling repetitive activity. Standard US Navy Tables provide safe procedures for dives up to 190 fsw for 60 minutes. Dives between 200 and 300 fsw were tested and reported in the exceptional exposure US Navy tables, including a 240 minute compartment. The Swiss tables, compiled by Bühlmann, incorporate the same basic procedures, but with a notable exception. While the US Navy tables were constructed for sea level usage, requiring some safe extrapolation procedure to altitude, the Swiss tables are formulated and tested over a range of reduced ambient pressure. The controlling repetitive tissue in the Buhlmann compilation is the 635 minute compartment.

While it is true that the table procedures just described are quite easily encoded in digital meters, and indeed such devices exist, digital meters are capable of much more than table recitations. Pulsing depth and pressure at short intervals, digital meters can monitor diving almost continuously, providing rapid estimates of any model parameter. When employing exactly the same algorithms as tables, meters provide additional means to control safety beyond table lookup. When model equations can be inverted in time, meters can easily compute time remaining before decompression, time at a stop, surface interval before flying and optimal ascent procedure. Profiles can be stored for later analysis, and the resulting data bank used to tune and improve models and procedures. Considering utility and functionality, meter usage should increase in diving, supported by technological advance in computing power, algorithmic sophistication and general acceptance, though it will probably be some time before tables are supplanted.

Meters

On the heels of growing interest in underwater science and exploration following World War 2, monitoring devices have been constructed to control diver exposure and decompression procedures. Devices, with varying records of success, include mechanical and electrical analogues, and within the past 15 years, microprocessor based digital computers. With inexpensive microprocessor technology, recent years have witnessed explosive growth in compact digital meter usage. All use the simple dissolved tissue gas model proposed by Haldane some 80 years ago, but given the sophistication of these devices, many feel that broader models can be incorporated into meter function today, increasing their range and flexibility. Although the biophysics of bubble formation, free and dissolved phase build-up and elimination is formidable, and not fully understood yet, contemporary models treating both dissolved and free phases, correlated with existing data, and consistent with diving protocols might extend the utility of diving computers. Approaches to treating bubble nucleation, excitation and growth in tissue and blood have been developed. In the industry, such new models are termed bubble mechanical, because they focus on bubbles and their interactions with dissolved gas in tissue and blood.

Decompression computers are fairly inexpensive items these days. Basically a decompression meter is a microprocessor computer consisting of a power source, pressure transducer, analog to digital signal converter, internal clock, microprocessor chip with RAM (random access memory) and ROM (read only memory), and pixel display screen. Pressure readings from the transducer are converted to digital format by the converter. and sent to memory with the elapsed clock time for model calculations, usually every 3-5 seconds. Results are displayed on the screen, including time remaining, time at a stop, tissue gas build-up, time to flying, and other model flag points, usually Haldanean (perfusion) tissue control variables. Some 3-9 volts is sufficient power to drive the computer for a couple of years, assuming about 100 dives per year. The ROM contains the model program (step application of model equations), all constants, and queries the transducer and clock. The RAM maintains storage registers for all dive calculations ultimately sent to the display screen. Dive computers can be worn on the wrist, incorporated in consoles, or even integrated into head-up displays in masks.

Statistics point to an enviable track record of decompression meter usage in nominal diving activities, as well as an expanding user community. When coupled to slow ascent rates and safety stops, computer usage has witnessed a very low incidence rate of decompression sickness, below 0.01% according to some reports.

Patterns of diving

Repetitive and decompression diving probably contend with a greater fraction of separated gas. And this makes extrapolations of bounce diving fits more difficult. In the early days, slower tissue compartments were added to accommodate deeper, prolonged, and decompression exposures. Ostensibly, slower compartments might track a greater proportion of separated gas, possibly dumped from tissues into gas micronuclei. Laboratory studies in decompressed gels bear witness to typical growth and elimination patterns in gas nuclei and bubbles spanning hours. Of course, bubbles and nuclei in the body are both perfused and metabolic, adding to complexity. While not always optimal, tissue response functions with very slow compartments can be coupled to critical tensions for repetitive diving. The approach is more limited for repetitive diving than bounce diving, as possibly witnessed by higher bends incidence in divers embarking on multi-day and repetitive activity, according to DAN. In such repetitive application, tables and meters which do not accommodate slower compartments, those longer than 60 minutes, appear further limited. For that very reason, the US Navy expanded the original set some fifty years ago, replacing the 70 minute compartment with an 80 minute compartment and adding the 120 minute compartment. Yet, the tendency today to add compartments in the several hundred minutes range, while well intentioned, is probably not the best means for tracking separated phases. Very slow compartments, in the several hundred minutes range, cannot really control multi-day and heavy repetitive diving by tracking just dissolved phases. Present consensus thus cautions against 3 or more repetitive dives in any 24 hour period, especially in the deeper categories (beyond 100 fsw), and relaxation periods of at least a day following 3-4 days of repetitive activity.

Repetitive Diving

The Haldane approach to repetitive diving parallels that for bounce diving. Critical tensions again limit permissible degrees of compartment saturation. However repetitive applications of dissolved gas models have not enjoyed the overall successes of bounce diving applications. Free phases in the tissues have had some time to grow between dives, and the next dive then pumps in a fresh supply of dissolved gas, possibly feeding phase growth if elimination has not been effective. Free and dissolved gas phase elimination time scales are generally not equal in any given tissue compartment, which is the root of the concern in multidiving. Some suggest that halftimes for free phase elimination are double those for dissolved phase elimination in the same tissue.

Multi-level Diving

Multi-level diving represents yet another dimension for application of the classical scheme, especially within table application, but less so with digital devices. The reason is not too complicated. Tables generally rely on the slowest tissue compartment to dictate staging and repetitive formats. Repetitive intervals are chosen so that the faster compartments cannot control the exposure upon surfacing, with 10 minutes the usual limit. Tables cannot account for gas uptake or elimination in faster compartments for short time intervals, and so require that short time intervals be added directly to exposure times. In multi-level table application, the 10 minute interval is neglected, and gas exchange in the faster compartments is not considered. At times neglect of the faster compartments causes trouble, especially when their critical tensions are exceeded with the tables blind for some 10 minutes. Because meters continuously monitor activities in all compartments, these table concerns are minimised in multi-level excursions. While such a problem is more an implementation issue than a fundamental issue, foregoing concerns in bounce, repetitive and decompression exposures still carry over here.

Schemes for multi-level diving are employed in the commercial, scientific, sport, and military sectors. One popular approach employs back to back repetitive sequencing, assigning repetitive table groups at the start of each multi-level segment based on the total bottom time (actual plus residual nitrogen) of the previous segment. At times, the method allows critical tensions, other than the controlling 120 minute compartment in the US Navy tables, to be exceeded upon surfacing. In the spirit of the US Navy tables, such circumstance is suspect, at least. But by tightening the permissible exposure window, and accounting for ascent and descent rates, the multi-level technique can be made consistent with the critical tension formulation of the US Navy tables.

In studying this technique, Wienke and Graver drew a line (envelope) across the US Navy Repetitive Group Table, separating multi-level dives violating at least one critical tension in the sequence from those violating no critical tensions. The line simply moves the no-stop time limits back a group from the US Navy no-stop time limits. Ascent and descent rates of 60 fsw/minute were assumed in constructing the multi-level envelope. Applying the back to back repetitive technique only to the safe side of the no-stop time limits maintains tissue tensions in the 5, 10, 20, 40, 80, and 120 minute compartments below the Workman critical values throughout the dive, and upon surfacing. Some 16 million multi-level dives were analysed on a CRAY XMP supercomputer in a few minutes, permitting construction of the envelope. Compared to the standard US Navy tables, the envelope, moving no-stop time limits back a group, also restricts the back to back repetitive method in same measure.

Systematically deeper to shallow diving practices are optimal in all cases. Deeper than previous excursions have the potential to excite smaller, more stable, gas nuclei into growth. Deeper spike and sawtooth diving profiles become more hazardous as repetitive frequency increases, probably due to the presence of growing bubbles and excitable gas nuclei in slower tissues and slingshot effect of higher tensions surrounding them.

Recommendations for safe diving

A set of discretionary protocols, not necessarily endorsed in all diving sectors, might be summarised as follows.

1. reduce no-stop time limits a repetitive group or two below the standard USN limits;
2. maintain ascent rates at below 18 m a minute, preferably slower and requisitely slower at altitude;
3. limit repetitive dives to a maximum of three per day, not exceeding the 30 m level;
4. avoid multi-day, multi-level or repetitive dives to increasing depths;
5. wait 12 hours before flying after nominal diving, 24 hours after heavy diving (taxing, near decompression or prolonged repetitive) diving and 48 hours after decompression diving;
6. avoid multiple surface ascents and short repetitive dives (spikes) within surface intervals of 1 hour;
7. surface intervals of more than an hour are recommended for repetitive diving;
8. safety stops for 2-4 minutes in the 3-6 m zone are advisable for all diving, but particularly for deep (near 30 m), repetitive and multi-day exposures;
9. do not dive at altitudes above 3,000 m using modified conventional tables or linear extrapolations of sea level critical tensions;
10. in short dive conservatively remembering that tables and meters are not bends proof.

Procedures such as those above are prudent, theoretically sound and safe diving protocols. Ultimately they link to free phase and bubble mechanisms.

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The above is composed of relevant extracts from a much longer paper submitted as a contribution to the dive computer workshop. The full paper is undergoing peer review.

THE DIVING INCIDENT MONITORING STUDY
DIVE TABLES AND DIVE COMPUTERS

Chris Acott

Introduction

This paper is an analysis of the data about diving computer and dive table use reported to the Diving Incident Monitoring Study (DIMS) to the end of 1993.

Method

The incidents reported to the Diving Incident Monitoring Study that involved decompression sickness (DCS) were examined for dive computer or dive table use. Incident reporting does not specifically analyse DCS incidents but can be used to examine the errors that contributed to the decompression accident.

Results

In the 880 reports received 433 involved "diver harm". Two hundred and twenty eight of these were involved reports of DCS, which was 26% of all reports.

There has been a gradual increase in the number of reports received in which a dive computer has been used to plan the dive, not only as the sole decompression guide but in combination with the use of dive tables. The percentages range from 10.4% in 1989-90 to 32.9% in 1993. Overall computers were used in 238 dives, 27% of the reports (Table 1).

In the incidents involving the use of a dive computer 90 resulted in DCS while the majority of the other 138 DCS incidents were associated with dive table use. However, there is an increased association between dive computer use and DCS when compared to those divers using a set of dive tables, while the rate of DCS amongst dive computer users and those divers using neither a dive computer nor a set of dive tables was the same (Table 2).

With deep dives, defined as dives to or deeper than 30 m, there was also an increased rate of DCS among those divers using only a dive computer, compared with those using a dive table. The rate of DCS among all divers using a dive computer, which includes the group using tables and a computer, was the same as those divers not using a dive table or dive computer to plan their deep dive (Table 3).

One hundred and seventy one incidents involved poor dive planning. The criteria were repetitive dives that were associated with a surface interval of less than 1 hour and when the deepest dive was the last dive of the day, although none of these dives were to deeper than 30 m. Of these poorly planned dives 93 involved "diver harm" with 67 cases of DCS. In the dives harming the diver there was an increased rate of DCS in divers using a dive computer compared with either divers using dive tables or using neither a set of dive tables nor a dive computer (Table 4).

Failure to understand or misreading a dive table was a contributing factor in 53 reports and 39 of these involved morbidity. The US Navy tables were cited as those the hardest to understand.

There were 72 reports where the dive profile was considered to be poor. The criteria were slow descent to depth, deepest part of the dive not being at the beginning of the dive and multiple ascents (yo-yo diving). Of these, 26 involved the use of a dive computer in which there were 18 cases of DCS (69%), 37 involved the use of a dive table in which there were 23 cases of DCS (62%) and 9 did not involve the use of a dive table or a dive computer in which there were 5 cases of DCS (56%).

In the 238 incidents where a dive computer was used there were few reports of computer failure (Table 5). The users of the four inaccurate computers all developed DCS, while only one of the two whose computers stopped working did so.

TABLE 1

COMPUTER USAGE IN 880 DIMS REPORTS 1989-1993

Year	Reports received	Computer alone		Computer and dive tables	
		Number	%	Number	%
1989-1990	125	10	8.0	3	2.4
1991	152	12	7.9	26	17.1
1992	266	27	10.2	49	18.4
1993	337	51	15.1	60	17.8
Total	**880**	**100**	**11.4**	**138**	**15.7**

TABLE 2

DECOMPRESSION ILLNESS IN 880 DIMS REPORTS 1989-1993

Diver used	Reports	DCS	%
Dive computers	100	40	40%
Dive computers and tables	138	50	36%
No computer or tables	103	37	36%
Dive tables or not recorded	539	101	19%

TABLE 3

DECOMPRESSION ILLNESS AND DEEP DIVES

Diver Used	Deep dives	DCS cases	% of Deep dive DCS	DCS % by dives
Dive computers	25	16	37.2	64
Dive computers and tables	26	12	27.9	46
No computer or tables	9	5	11.7	56
Dive tables or not recorded	52	10	23.2	19
Both groups of computer users	51	28	65.1	55

TABLE 4

93 REPORTS WHERE A POOR DIVE PLAN CAUSED HARM

Diver used	Morbidity	DCS cases	
Dive computers	16	15	(94%)
Dive computers and tables	9	8	(89%)
No computer or tables	44	25	(57%)
Dive tables or not recorded	24	19	(79%)
Total	**93**	**67**	**(72%)**
Both groups of computer users	25	23	(92%)

TABLE 5

PROBLEMS NOTED WITH 238 COMPUTERS USED

Problem	Number	Harm	DCS
Computer stopped working	2	1	1
Computer inaccurate	4	4	4
Unable to read numbers	2	-	-
Forgot to activate computer	1	-	-

Conclusion

From DIMS data there is an increased association in the rate of DCS in dive computer users when compared to those divers using a dive table. This is particularly evident in dives that are to 30 m or deeper. However, to discover why there is this increased rate of DCS in dive computer users would require a study in which many factors are controlled and standardised. However DIMS data shows that dive computers are mechanically reliable.

The deepest dive not being the first dive of the day is common. Poor dive profiles are not confined to any one group of divers and show a lack of understanding of gas uptake and elimination. A failure to understand the US Navy Tables may indicate poor diver education.

Repetitive dives following a surface interval of less than one hour are not uncommon. Repetitive dive planning does not appear to be made any easier or safer by using a dive computer. Repetitive dives that are unplanned, that is using neither a dive computer nor a dive table, have the same risk of DCS as those dives planned using a dive computer among DIMS incidents.

The same DCS rate among divers who planned their dives using a dive computer and those who did not use a dive computer or dive table may indicate the random nature of DCS.

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DIVING WITH COMPUTERS

A Personal view

David Davies

Since I began my love affair with diving I have seen many changes both in attitude and equipment and, in general, have agreed with the direction recreational diving has been heading although there are still some trends I would like to see reversed such as the deterioration in the level of water skills that new divers seem to have.

In the early days, diving tables, which we now take for granted, were rarely used and if they were used, the only ones available were the US Navy tables. However, as many divers at that time dived with neither watch, contents gauge nor depth gauge any thought of table use was really superfluous.

Once diving started to become more popular and there developed a demand for more and better equipment and formal training in its use, then these items became more readily available, mandatory for the well dressed diver and increasingly recommended by dive schools who could see the prospect of extra sales at the end of each course. These schools then began to teach their students how to use this equipment and how to read the dive tables. The Wilks and O'Hagan article in the SPUMS Journal in 1991[1] showed just how effective this training was and how little the students remembered of the intricacies of these tables once they had completed their basic course. Experience gained in the navies of the world with these tables suggested that if "fudge factors" were used in conjunction with the tables there seemed to be a lower incidence of decompression illness in their divers. These factors included reading a deeper depth than actually dived, reading a longer time than actually spent on the bottom, ascending slower than the arbitrary 60 feet per minute and having a rest near the surface prior to the final ascent.

Development of the microchip allowed the introduction of small computers for business and then personal use. Some lateral thinking led to the development of a submersible device which could calculate the theoretical uptake and distribution of nitrogen in theoretical tissue compartments according to an built in mathematical model by measuring the depth and time at frequent intervals during the dive. The resulting display gave the diver an indication of how long he could remain at depth before requiring decompression stops. As a result he could alter the dive plan, during the course of the dive, and gain more bottom time. These early computers were notoriously unreliable and were based on the US Navy table algorithm with the assumption that the rate of elimination of nitrogen was the same as the rate of uptake by the tissues.

When dive computers were originally introduced it was the veteran divers who first appreciated their value. They used the instrument as an accurate depth and dive time recorder and on the basis of their experience added their own "fudge factors" depending on prevailing conditions, just as they had done before with the tables, and they modified their bottom times accordingly.

Then began an intense promotional campaign by manufacturers, distributors and dive shops who realised that there is more profit in selling an expensive computer than a cheap set of tables. As a result, less experienced divers became aware of this additional item of equipment which they could show off to their companions and brag about their increased depth, bottom time and "safety". They dived for the times and depths specified on their computers and often failed to add in the fudge factors that their more experienced senior colleagues had been doing. They forgot that they should not be sharing computers or that buddy pairs did not dive identical profiles and some problems arose. As it was still an expensive piece of kit the computer became somewhat of a status symbol and the computer diver tended to belong to that group which had the best equipment, dived often and had extensive overseas diving holidays.

SPUMS members seemed to be the exception possibly as a result of several powerful articles published which slated the use of dive computers and extolled their vices. These articles were written by authors who had eminent standing in the diving medical community and who made anecdotal reports of a few cases of divers suffering from decompression illness after diving with a computer.

Now, more recently, many dive schools have started adding a computer to all their loan and hire gear so that novice divers being introduced to the sport now have a computer to look at rather than trying to juggle their minds between the watch, the depth and contents gauges and their copy of submersible dive tables. Their introductory course gives them only a cursory instruction in use of the tables so that, basically, they know no other way of diving than with a computer.

Just as most drivers have no real knowledge of how the brakes, motor or ignition systems work in their car so do these new computer divers have little knowledge of what the little black box on their wrist is doing and why they are getting the display that they are seeing. It is this new generation, brought up in the belief that the computer is omniscient, accurate and infallible, which sorely requires proper education in the science of diving but this subject is being neglected by the educators with the result that, in the event of a computer failure, these divers have no fall back position on which they can rely.

This group has been thoroughly inculcated about the desirability of slow ascent and has a firm adherence to the myth that spending five minutes at five metres at the end of every dive can overcome any transgression of depth or time during the dive and so be a "safe" diver.

Initially the mathematical model for these computers was based on the US Navy tables but as development progressed and more experience was gained the developers incorporated other more "conservative" algorithms based on the Bühlmann, Bassett and DCIEM tables. As a result, different computers subjected to the same dive profile can display significantly different permissible bottom times, ascent rates and decompression stops. This can be a source of great confusion to the buying public and has led to increased competition between the manufacturers and distributors to promote the "safest" dive computer. It is my impression from talking with divers that prior to the purchase of a new computer, many divers will compare the published bottom times for each and go for the one that gives them more dive time with shorter surface intervals.

Interestingly, there does not appear to have been a significant change in the numbers of cases of decompression illness presenting for treatment since the widespread introduction of this instrument.

Scientists and diving doctors have long known that physiology of the human body does not conform to a strict mathematical model. The blood flow, rate of metabolism, temperature and a multitude of other factors alter from tissue to tissue, moment to moment according to prevailing circumstances and this cannot be programmed into any computer. The current generation of computer cannot make allowance for fatigue, dehydration, hangover, sea sickness, work levels before, during or after a dive, age, experience, anxiety or the presence of an undetected patent foramen ovale. They make no allowance for variations either between divers or within the one diver over the course of the dive, the day or the week. This may well change in the near future as computers become more sophisticated, the programs are improved and more environmental parameters are monitored. The computer will not, however, monitor variations in regional blood flow, tissue metabolism or tissue oxygenation although new computer models are now monitoring body surface temperature and variations in breathing gas consumption as a reflection of the work of diving. These instruments may also have the capacity of having their stored data transferred to another computer which, at a later time, can then be used to track the course of the dive minute by minute. As a research tool this opens up many possibilities as to the aetiology of bubbles and the origin of decompression illness.

My personal experience with a computer is over only 35 dives. Prior to its purchase and use I would invariably return from any diving trip, be it one dive or several dives, utterly exhausted. If I had a dive first thing in the morning the rest of the day was a write off.

In retrospect and after a great deal of navel gazing I attribute this to showers of microbubbles and I constantly give thanks that none of these ever became symptomatic. For thirty years this has happened even though I rarely dived deep and, apart from the occasional emergency ascent when the hookah ceased to function, always tried to ascend slowly. Hand over hand up the anchor rope was the usual practice. Since I began to use a computer which has a 10 m/minute ascent rate alarm I no longer have the fatigue and lethargy and I am much happier with my diving. My wife has even remarked that I am now able to mow the lawn after an early dive, something which was beyond me before. Certainly this is anecdotal but it is my experience.

Computers are not infallible. Divers still get bent, but, is this the fault of the computer, the diver, or is it just a random event? If computers are so dangerous as some of our senior colleagues seem to suggest, why is there no significant change in the number of bends cases presenting for treatment? All accept that the computers currently on the market are accurate depth gauges and time keepers. Most computers now activate automatically on entering the water, something watches never did. They all have large numbers that are easily readable underwater which my watch never had and I find increasingly useful. They have all the required information in the one convenient field so that the diver does not have to look from watch to depth gauge to contents gauge to submersible dive tables and then do quite serious mental arithmetic to estimate how much longer he can remain at that particular depth. Most computers have a rate of ascent alarm which encourages the diver to ascend at or slower than the recommended rate. The newer models are using the 10 m/minute rather than the former 18m/minute. Prior to this divers had been measured ascending at anything up to 40 m/minute. My message here is that the computer is a compact device that, provided you read and understand the manual, is easy and convenient to use. Like computers in other walks of life they are becoming relatively cheaper to own and more reliable in the field.

Just as dive tables had their limitations, so do computers in that their algorithms cannot be pre-programmed to cover every contingency. Dives must learn that the computer is there to provide guidelines and to dive safely the diver should remain within these guidelines and not push them to the limits. Doctors and scientists who continue to argue against the use of computers for recreational diving on the grounds that the algorithms have yet to be properly tested, the algorithms are incomplete, the computers may occasionally fail during the course of a dive and the computers make no allowance for physiological changes between divers and over a period of time seem to forget that the computer is here, and is here to stay. With time dive computers can only get better.

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WHY I USE A DIVE COMPUTER

Guy Williams

I began using a dive computer in the late 1980's, when the first of the modern generation of dive computers came onto the market, and have been using one ever since, although I have updated the model three times. Before this I used a conventional set-up with contents gauge, watch and depth gauge. My first depth gauge was an old oil-filled gauge (a not particularly accurate instrument, and like most divers I never had it serviced) with no maximum depth indicator (MDI), I updated this unit to a more modern model unit with an MDI, and I noted that many of my dives were suddenly deeper than I had previously recognised. I continue to use a dive watch, but only to tell the time. I recall not infrequently descending on a dive, thinking about photography and my camera gear and forgetting to set the bezel on my watch. I believe most of the audience have done this at least once, a computer does this automatically.

At least with a computer, it only requires to be activated before entering the water, everything else is automatic. Computers log depth and time with great accuracy, and as a bonus offer advice on decompression/no-decompression requirements, again without requiring any input. Previously I was a user of the US Navy tables and later the PADI recreational tables. I saw in a recent review in Pressure, that a US Navy survey produced 75% incorrect answers on table usage. Unfortunately no one seems to have a copy of this survey so I cannot test myself. If divers, as they do, run out of air because they do not look at their gauges, how can we expect them to look up the tables, and follow them accurately.

My first computer was an early Oceanic Datamaster, with air integration, I found this a great step forward. It was easy to operate, had a clear display and was very accurate. I could spend more time enjoying my diving and less time on the procedural aspects of diving.

I now use the a current model of air integrated Datamaster. I find it a delight to use. However computers are not yet perfect. I have had computers fail, but only on the surface during the power-up self check. I should add that the Australian diving industry is excellent with replacing defective equipment under warranty. I carry a spare computer, partly because I believe that all computers can fail and therefore a backup is useful. I also carry a Spare Air, so I guess I like spares. However the main reason is that with a gauge on the end of a high pressure hose, and my eyes on the viewfinder of my camera, I find the best position for a gauge is beside the viewfinder. I would prefer a wrist mounted unit as I am used to gauges on my wrist. However this is the year that air integrated hoseless dive computers have appeared on the market, so perhaps in the future Sony will incorporate a dive computer's display in the viewfinder of their cameras.

I believe that air integration is a useful feature, as it accurately predicts a recommended dive time, based on my air consumption or on no-stop limits, whichever is least and to allow enough time to ascend safely. Another useful feature is a low air warning, a number of computers now produce an audible warning when air levels are low and a persistent warning when air reserves are critically low. The audible warning also alerts other divers in the vicinity, if they are aware of its significance.

At last year's meeting Chris Acott presented details of his diving incident survey, in which being out of air or low on air was a significant factor in many incidents. I believe air integrated dive computers will make this much harder to achieve.

Another feature of my dive computers, and I believe some others, is an ascent rate warning, i.e. if I exceed the recommended ascent rate there is a visual and audible warning. I find it interesting the number of times that the ascent rate warning beeps and flashes, on dives when I would not have noted an excessive ascent rate, particularly on dives with no reference point for ascent, such as an anchor line or reef. Perhaps another feature that could be incorporated in future computers is a descent rate indicator, this would be useful for diving Pelilu Comer in Palau, with its vertically down currents.

I also like the bar graph depicting my nitrogen loading, if I follow the manual and stay out of the caution zone, then I always remain 10 minutes outside the no-stop limits, combined with a 5 minute safety stop. I believe this is a useful safety feature. It is informative to see my progress towards the nostop limits. I should add that I have read the manuals that came with my dive computers, on more than one occasion.

Dive computers, like all instruments need to be cared for. I am careful to protect it from excessive trauma, and I keep it in my buoyancy vest pocket, to protect the gauge and the reef from accidental damage. At the end of a day's diving I usually take my regulator and computer back to be rinsed in fresh water. I carry a spare battery, and change the battery regularly.

One problem is, if I am diving with a partner who is not familiar with my computer's display, the buddy does not appear to understand it. A computer display can be a little confusing if not seen before. This is especially important with the wide variety of models on the market, and the number continues to increase.

I also like the concept of multilevel diving, especially on SPUMS trips. At home in Melbourne most of the diving is square profile. I have tried a PADI Wheel and even had lessons on how to use it from Ray Rogers. However it is much easier to use a computer, as it makes multi-level diving a breeze and diving more enjoyable.

The ability of computers to log previous dives, makes completing log books easier and enables divemasters to check dive profiles. Divers presenting with diving related medical problems can retrieve their dive log from the computer. In the near future more computers will allow details to be down loaded onto a PC. At least one major supplier of dive computers is planning to supply hyperbaric units with free interfaces to suit its computers.

In the near future there will be even more models of dive computers on the market, with interfaces to down load dive details and user modifiable parameters, i.e. the user can make the unit even more conservative. Some newer models are programmed to compensate for water temperature and diver work. One manufacturer even proposes a head-up display in a scuba mask. One model now allows for software upgrades.

After discussions with a variety of dive shop proprietors it is clear that a large number of divers are buying computers and not dive tables. They dive shop owners feel that in the not to distant future only computers will be sold.

In the future we will have computers controlling rebreathers, and one manufacturer is considering a wrist mounted GPS (global positioning system) unit to replace the compass.

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DIVE COMPUTERS

John Lippmann

Some of the newer "multi-level" tables include methods for compensating for parts of a dive spent shallower than the maximum depth. However, the ideal situation is to have a device that tracks the exact dive profile and then calculates the decompression and air requirements for the actual dive.

In the early 1950's, the United States Navy formed a committee to identify equipment modifications and improvements that were necessary to accommodate the newly introduced scuba operations. The committee published a report which incorporated a design of a diver-carried analogue computer which simulated nitrogen uptake and release in two theoretical tissue compartments. It also discussed what it described as the "Ultimate Gauge," an electrical analogue device which would indicate both the decompression and air consumption status of the wearer so that the diver would know if he had enough air to complete any required stops.[1]

Decompression meters and dive computers began to appear around the mid-1950's. Probably the best known of the early devices is the *SOS decompression meter*. This unit was designed in 1959 and is still commercially available today. It incorporates a ceramic resistor through which gas is absorbed and released. The pressure built up inside the unit would determine the required decompression.

In the following years, various organisations including Farallon, DCIEM and others experimented with a variety of pneumatic, electrical and electronic decompression calculating devices. By the mid-1970's, with the advance in microprocessors, it became possible to construct a relatively small computer capable of doing multi-level calculations.

1983 saw the release of two microprocessor computers which were specifically designed for recreational divers. One was the *Decobrain,* produced in Switzerland and the other was the US produced *Edge*. These initial units were large, relatively expensive and prone to problems. Improved technology has overcome some of the early technical restraints and over past several years we have seen the introduction of affordably priced computers that offer more accurate depth and time recording, together with multi-level decompression calculations.

Some early dive computers had decompression tables programmed into their memory and read the tables to give the diver appropriate decompression information. However, most dive computers are programmed with a decompression model, rather than a set of tables. The current generation of computers are based on various derivations of either the Bühlmann (ZH-L) system or a modified US Navy system.

Dive computers offer the diver a number of advantages over the tables, which include:

1 Eliminating the problem of divers making errors in their decompression calculations since the computers do the calculations automatically and accurately in accordance to their model. Divers commonly make mistakes when using dive tables.[2,3,4]

2 Allowing the diver much more dive time on most dives, especially repetitive dives since computers use the actual dive profile, rather than just the maximum depth, and account for a variety of tissues compartments, rather than a single tissue compartment during a surface interval as most tables do.

However, some people remain critical of these devices. Some argue that a diver will become too machine-dependent, forgetting or never learning certain basic principles of safe dive planning. Probably the main criticism centres around the fact that there have been too few well-controlled, documented tests to determine the validity of multi-level and multiple repetitive dive applications of the various models used by the computers.

The decompression models programmed into the computers are designed to simulate nitrogen uptake and release in a diver's body. Most assume that nitrogen uptake and elimination both occur exponentially. Most early dive computer algorithms assumed that uptake and elimination occur at the same rate and some still do.

Gas kinetics within a diver's body depend upon a variety of factors which include perfusion, solubility of the gases, and diffusion. Factors such as exertion during the dive, carbon dioxide levels and temperature complicate the process, and once bubbles have formed the process becomes even more difficult to predict. Although certain algorithms still assume identical rates of uptake and release, several programmers have now attempted to account for a significantly slower rate of elimination.

However, these algorithms are just mathematical models; some with a firmer physiological basis than others. They cannot completely predict the gas flow in and out of a diver's actual tissues and the possibility of decompression illness (DCI).

Are computers safe ?

Over the past five years or so the market has been flooded with various makes and models of dive computer which have been marketed aggressively. Some of the advertising was, and sometimes still is, quite misleading. It has often been incorrectly suggested that computers were more conservative than tables for rectangular profile dives (ie. those where most of the time is spent at the maximum depth). Although this may be true for an initial dive, it was and is still rarely true for repetitive rectangular dives and repetitive dives cause more DCI than single dives.

Because of some of the "technocrap" included in certain advertisements, a reader could easily be mislead into believing that these magic little boxes are scientifically sound and validated. Unfortunately, they are still subject to varying amounts of intelligent guesswork.

More colourfully, divers were encouraged to get increased value for money on their diving holidays by buying a computer and so getting far more underwater time during their vacation. Some of these advertisements even provided the monetary calculations, including the relative prices per hour underwater.

In their enthusiasm, many of these eager proponents of dive computers lost sight of the fact that, in reality, very little was known about how well the various units would perform, or were already performing, in the field.

Millions of dives have been done by divers using dive computers, most of them without incident. Unfortunately, since most of these dives are undocumented, it is still unknown exactly what sort of profiles divers are doing with apparent safety.

One report, published in 1990, gives details of around 44,000 dives made using computers, conducted from a particular vessel. There was only one reported case of decompression illness in a computer-user (although others might have gone undetected or unreported), and this diver had misused his computer.[5] Most of these dives were made using a particular type of computer which utilises a decompression model which is comparatively conservative in many situations. In addition, divers appear to have been well-briefed on certain aspects of safe diving practice, including slow ascents and safety stops.

With so many apparently "safe" dives carried out by computer-users, it might appear that the computers are reasonably reliable predictors of DCI. However, as with most tables, it is difficult to determine whether it is the computers themselves that are safe, or if the apparent safety lies in how, and under what conditions, divers are using them. Since most dive profiles are not fully recorded and documented, it is not known whether or not the divers dived to the limits given by their computers. If the units are not dived to their limits then we still do not know how good the actual limits are. This is especially relevant to multi-level and repetitive dives.

From 1987 to the end of 1991, 653 cases of DCI in divers using computers have been reported by the Divers Alert Network (DAN) USA. The number of cases has increased over the years, with computer-users representing from 15% of the DCI cases in 1987, to 45% of the cases in 1991.[6] The increase is probably mainly due to the far wider usage of dive computers.

The DAN USA data indicate a trend of around 80% of the decompression illness cases in computer-users occurring after dives deeper than 24 m; and a similar rate for repetitive dives. Overall, the 1987-91 DAN data suggest that computer-users have a higher DCI incidence after deeper dives or repetitive dives than do table-users.[6]

Data of diving incidents in Britain in 1990 indicates that 34% (27/80) of the divers who suffered DCI that year had dived within the limits of their computers.[7] In 1991, computer-users represented 29% of the 100 divers treated for DCI in the UK. Analysis of the British data shows that the vast majority of the DCI cases in computer-users occurred after dives deeper than 30 m.[8]

Australian data indicate that approximately 22% of a group of divers treated for DCI in Queensland between October 1989 and January 1993 had been using a dive computer.[9] A survey conducted in Queensland during 1990 suggests that possibly 5% of certified divers in Australia were then using a dive computer.[10] No doubt the proportion of users has grown considerably since then. A 1993 survey of Queensland diving instructors indicated that 46% of the 202 respondents owned a dive computer.[11]

The data to date cannot be used to confirm whether or not dive computer use is associated with an increased risk of DCI. Increasing computer usage will inevitably lead to an increase in the percentage of computer-users represented in DCI statistics.

However, it is obvious that divers can and do get DCI while using dive computers, although the likelihood will depend, to some extent, on how a diver uses his or her computer. Sometimes DCI results because the diver disobeys the advice given by the computer (or table). On other occasions, divers have suffered from DCI after diving well within the limits of the computer (or table).

Diving practices

An analysis of the DAN DCI statistics for 1987 and 1988 showed that those divers using computers were diving deeper than those using tables.[12,13]

Interestingly, DAN USA data indicate that in 1987, 64% of all the divers treated for DCI in the USA had done repetitive dives, whether using computers or tables. This increased to 78% by 1991.[6] The overall increase in DCI after repetitive diving may indicate that more divers are doing repetitive dives. However, it may partly be a consequence of divers attempting to maximise dive time on multi-level and repetitive dives by using decompression systems such as dive computers and certain tables which are less conservative than traditional tables for repetitive diving.

There is no doubt that computers and multi-level tables have greatly influenced diving practices. Divers are certainly spending far longer underwater, especially on reef dives where multi-levelling is more appropriate. Multiple repetitive dives, previously very restricted because of table constraints, are now commonplace, especially on live-aboard dive boats. The vast majority of these divers have no apparent problems.

Computers have also helped to teach divers to come up more slowly. Most incorporate fast ascent warnings which encourage divers to slow their ascent, especially near the surface. This feature is certainly an aid to safety and a major benefit of a computer.

Computer users often do multi-level dives. Despite the lack of scientific evidence to determine the safety of most multi-level techniques, the tests that have been done as well as experience in the field and computer simulations of gas kinetics appear to indicate that certain profiles may be associated with a lower risk of DCI. It appears that working shallower throughout a dive is a sensible practice, whereas working progressively deeper during a dive would appear to carry a higher risk.

Data from dive computer usage several years ago indicated a very high incidence of DCI after dives involving mandatory stops.[12,13] This incidence appears to have dropped over the last few years.[6] This may be a result of more conservative programs of late, or it may mean that fewer divers are doing decompression stop dives using computers.

High risk dive profiles for computer-users (and in most cases tableusers) appear to include:

deep dives, especially deep repetitive dives
decompression stop dives
multi-day repetitive dives
multi-level dives in which a diver descends deeper, rather than working shallower, during the dive.

Just as divers sometimes make mistakes when using tables, dive computers sometimes fail. Appropriate precautions need to be taken in case of computer malfunction. In an Australian survey conducted late in 1992, 29% of the divers who reported using a computer had experienced a computer failure.[9] This is a very real problem that needs to be addressed by the manufacturers, and accommodated to by divers who are using dive computers. Fortunately, most failures appear to occur on the surface, rather than underwater.

Advantages of dive computers

Avoid calculation errors common with tables.

Greatly extend dive time.

Increased flexibility during dive.

Can provide visual and audible safety warnings.

Can provide an accurate record of dives.

Disadvantages of dive computers

Accuracy of multi-level limits is unknown.

Longer available dive times can increase DCI risk unless dives are conducted sensibly.

Can encourage poor dive planning.

Can fail.

Future dive computers

Armed with the knowledge gained over the past few years, those who program dive computers now have a better idea of the shortcomings of their models and some have taken significant steps to improve the safety of their products. Certain computers have become considerably more conservative in the no-stop times they allow (and decompression stop times they require), especially for repetitive dives. The programmers will continue to address more of the shortcomings of dive computers, including their current inability to alter appropriately the gas dynamics in the model in reaction to a diver participating in diving practices generally believed to be associated with a higher risk of DCI. Future models will attempt to further address problems such as very rapid ascents, deeper repetitive dives, multiple ascents, exertion and cold. They will become more "reactive" to what the diver actually does during the dive. However, it is currently impossible to address most of the shortcomings adequately due to a lack of data on which to base appropriate models. DAN USA is attempting to build a very large database from which important information about diving practices can be gleaned. Ultimately, this will enable the decompression algorithms on which both computers and tables are based to be improved significantly.

Despite all the gaps in our knowledge of DCI, and the resulting uncertainty associated with predicting its occurrence, dive computers will continue to improve in leaps and bounds in the future and will provide more and more information and advantages to the diver. They enable the opportunity to provide valuable audible and visual safety warnings of both decompression and air status and so can be used to facilitate safer diving.

There is no doubt that dive computers are here to stay. For many divers, tables have become a relic of diving days gone by. The trend will continue and eventually tables may not be taught on most dive courses. However, divers must be thoroughly educated in a computer's use so that they are familiar with the particular computer they are using, aware of the shortcomings of that computer and with the safe diving practices that should be adopted when using a computer.

Safe dive computer usage requires

A diver educated in how to dive with the computer.

A reliable, conservative computer.

Adherence to safe diving practices.

A certain amount of good luck (which is also true with tables) !

Suggested practices for using a dive computer

When using a dive computer:

Ascend slowly. Never exceed the ascent rate recommended by the computer, and generally ascend at about 10 m/minute or slower when shallower than about 24 m.

Go to the maximum depth early in the dive and progressively and slowly work shallower. End the dive with at least 3 minutes at 5-6 m. Avoid rectangular dive profiles.

Make repetitive dives progressively shallower.

Do not dive right to the limits given by the computers. The limits may not be reliable, especially for repetitive dives. Computers, like dive tables, do not cater for individual susceptibility to DCI. These factors must be considered when deciding when to ascend to the safety or decompression stop and how much time to be spent at that stop. Reduce the limits progressively more for each dive in a series of repetitive dives. This is especially important when repetitive dives are conducted over multiple days. Also reduce the limits if multiple ascents are made within a dive or if you become cold, anxious or exert yourself during the dive.

In the event of a computer failure during a no-stop dive, and, in the absence of an appropriate back-up, ascend slowly to around 6 m and spend at least five minutes there before surfacing. If a mandatory stop(s) was indicated before the computer failure and you cannot remember it, spend as much time at around 6 m as possible (unless deeper stops were previously indicated), leaving enough air to return to the boat safely. Do not re-enter the water for at least 18 hours, or for the time needed for the dive computer to totally off-gas (had it not malfunctioned), whichever is longer.

If using a dive computer for multi-day, repetitive diving, take a break around the third day to allow your body to rid itself of some of the extra nitrogen load it has accumulated.

Do not begin to use a dive computer if you have dived in the previous 24 hours.

Ensure you are well hydrated before and after diving.

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WHAT I LIKE AND DON'T LIKE ABOUT DIVE COMPUTERS

John Knight

What do I like about dive computers ?

The one word answer is convenience. They save the diver from decompression table calculations during a dive. Divers often go below the planned depth and so need to calculate an new dive or decompression time under water.

Tables were originally developed for naval diving. The divers were puppets manipulated by a puppet master, the dive superviser at the surface, who controlled their every movement. He did the decompression calculations. The diver's depth was known to the supervisor and the divers usually stayed at one depth. Such disciplined divers do not have to think about tables while underwater, they get told when to come up and when to stop on the way. This is not the way that recreational divers dive !

Few recreational divers do square dives. All decompression theories allow multi-level dive decompression requirements to be calculated. Using tables to do this is complicated and requires thought underwater. Even with the PADI Wheel thought, manual dexterity and accuracy are required. Complicated thinking is more difficult and less reliable under water than it is on the surface. Dive computers perform automatic calculation of the dive profile and of the estimated nitrogen load during the dive and of the remaining no-stop time.

A dive computer allows one to do a multi-level dive without having to worry about whether one has ascended the right amount to suit whatever multi-level dive one is allowed by the tables. The computer does the calculations. A relatively safe no-stop dive can be done by going deep first and well before the no-stop time for that depth is reached on the computer, going shallower and repeating the process again and again.

Another reason for using computers is that recreational divers are bad at using tables. In 1988 I asked those attending the SPUMS Annual Scientific Meeting to do a short test on the tables.[1] Less than half (19 out of 50) of those who collected a question sheet returned it and only ten got every answer right.[2] This bore out a report from America[1] which showed that only 19% of a group of commercial divers and instructors could get the answer right. In Queensland 45% of divers tested answered the first question correctly and only 36% got the second right.[3,4]

It is quite clear that trainee divers are not taught to use the tables thoroughly enough so that they remember how to use them after months without diving. Tables are relatively easy to use for a single dive. Many divers get into trouble calculating the second dive time. People have trouble with the concept of residual nitrogen. With Nu-way and similar tables showing available time and residual nitrogen time in different colours people often pick the wrong colour numbers.

In fact recreational divers are so bad at using the tables that many dive charter boats in Australia have a divemaster who calculates and announces every diver's second dive time just to be on the safe side ! During the last few years in Victoria the increased use of dive computers has made this calculation unnecessary for a growing number of divers.

A third reason for liking computers is ease of use. First one has to read the instruction book to find out what the display shows. Although all computers display the current depth, time underwater and no-stop time remaining there is no standardisation of which figure goes where. But once one has found this out one can dive safely, at least for the first dive.

The elapsed dive time and the time to a no-stop limit are usually displayed. This quite definitely is an improvement on using the tables and suddenly finding, when you look at the maximum depth indicator on your depth gauge that your 18 m dive had turned into a 21 m dive without you realising it.

Algorithms

Tables and computers are only as good as the algorithm that they are based on. Uptake and elimination of gases are modelled with equations, usually representing the body as a series of compartments that fill up with gas at different rates. In most tables gas is assumed to be excreted at the same rate as it went it. Anaesthetists have known this to be untrue since the early 1960s. Only relatively recently has this been accepted by the diving community. However, for single dives it does not seem to matter what the mathematics are as long as they result in initial no-stop limits close to, but not exceeding, those of the USN. The British Sub-Aqua Club/Royal Naval Physiological Laboratory (BS-AC/RNPL) tables treated the body as one compartment while the United States Navy (USN) tables used many compartments. But the no-stop limits were very similar. The new USN probability of decompression sickness (DCS) tables are based on a two compartment model which was a "best fit" for USN DCS results, while all the dives were done using a multi-compartment table. The Defence and Civil Institute of Environmental Medicine (DCIEM) tables use 4 compartments and are based on the results of many years of experimental diving at DCIEM and with the Canadian Forces. They have been continuously modified since they were first issued in 1983.

A few early computers "looked up" existing tables. Most computers use table algorithms to calculate the nitrogen load at frequent intervals. Different brands of computers use different algorithms. Many are based on the Spencer no-stop limits model as modified by various developers and others are based on Bühlmann's Swiss model. The latter tend to give shorter bottom times.

In practice it does not matter which table is marginally safer for the diver unless the diver uses it properly. Simplicity makes using a table correctly easier. The DCIEM tables have 2 sides and a separate multiplication table. The BS-AC 1988 tables have 7 sheets to look up depending on surface intervals, depths and number of dives. The PADI wheel can easily be misaligned.

The only table that requires no calculations is the Bassett tables formatted by John Lippmann and myself. It was designed for a diver to put a finger on a number and get the answer by sliding the finger along a line either vertically or horizontally or both. It also has three fudge (safety) factors built in for the first dive and five for the second compared with the USN tables.

Safe use of tables and computers

Whether a diver uses tables or computers there are certain basic steps needed to dive safely.

To use any table properly one has to know how to use it. Unfortunately many divers do no know. Then one has to know the maximum depth of the dive, which with recreational divers is seldom the planned depth of the dive!

Going deeper than planned should mean recalculating the no-stop dive time, or the decompression required, during the dive. In my experience, except when using the Bassett tables, this exercise often turns out to be on a par with solving a cryptic crossword clue. The Bassett tables require no thought, only the movement of a finger horizontally or vertically, to find the new time.

Many Bourdon tube depth gauges are inaccurate. Some are safe because they read deep but as many are dangerous as they understate the depth. Very few divers have their depth gauges checked frequently. On the whole dive computers have relatively good time and depth sensors.

To use tables one needs to know the time underwater. Who here has never forgotten to set the watch bezel at the beginning of a dive ? I bought a Citizen Aqualand because it turns itself on, when in diving mode, and will beep at me if the depth or time that I have set is exceeded.

Ascent rates are important. It is difficult to maintain 18 m/minute or less using a watch and depth gauge. A computer with an ascent rate alarm, especially with both audible and visual alarms, makes it much easier.

Computers

Dive computer manufacturers and distributors claim that their computers are more conservative than the USN tables for single no-stop rectangular profile dives. Studies support this, but there is a wide variation in no-stop bottom times between various computers.[5,6] However, this apparent conservatism is lost once the dive profile becomes multi-level and does not apply to repetitive dives.

The first computer to have mass sales was the Orca Edge. It has a very convenient graphic display which darkens from the top as one goes deeper and from the left as one stays underwater. This shows its calculation of nitrogen uptake and excretion. It displays the diver's depth, bottom time and Spencer-Huggins no-stop time remaining in figures. By ascending when the dark area of the array nears the no-stop curve, or keeping away from the edge, it is easy to manage a no-stop dive. Safety factors can be added by keeping an extra pixel or two from the curve. It will tell the diver that it is time to ascend and the depth to which he or she must rise to do any decompression stop. It will tell the diver how long to stay at the decompression stop. Of course it has its drawbacks. One is that it weighs a kilo and another is that will allow dives that are dangerous such as diving to 30 m for 10 minutes without a stop, have a one hour surface interval, dive again to 30 m for 10 minutes, again without a stop, have another hour surface interval, dive to 30 m for 10 minutes, again without a stop, and so on.[5] Leakage was a significant problem with some models of Orca computers.

Many people, myself among them, have reservations about the algorithms of computers which allow such dives. When the Edge, Skinny Dipper, Delphi (all made by Orca) and Suunto SME-ML were tested to see if it would allow a series of "bounce" profiles, known to produce DCS, they were shown to permit them.[5,7] They also allow, without decompression penalties, diving deeper than the first dive on the second and later repetitive dives.

Most computers switch on automatically when contacts are wetted. But most have to be in the air for a period of time for the computer to run through its internal checks or it refuses to work underwater. The Beauchat Aladin Pro and Suunto Solution, which have different algorithms, do not require these in the air checks.

Air integrated computers, which monitor cylinder pressure, turn themselves on when the air is turned on and display of cylinder pressure with or without remaining air time at that depth. I have been using an Apollo cylinder pressure and depth gauge, which also times the dive and surface interval, for some years. It also displays the remaining air time. I have had some very odd remaining air times depending on my breathing pattern, but I do like the graphic of the emptying tank. Air integrated computers should make it more difficult to run out of air unexpectedly.

The latest generation of dive computers comes in two parts, a pressure monitor with a built in radio transmitter, which allows the high pressure hose, and the contents gauge on the end of it, to be eliminated, and the wrist worn computer which presents all the information including air status. This eliminates the problem of a high pressure hose blow out but could introduce new problems. Time will tell. Only one computer in this configuration is actually on the market. It is sold as Cochrane, Sea Hornet and Mares. There are rumours that there have been various teething troubles. The Uwatec Air-X is being advertised widely but is not yet available (May 1994).

Risks of using computers

Whether dive computers increase or decrease the risk of decompression illness is a question that is unlikely to ever be answered, because the number of dives performed with computers or tables is unknown and never will be known for certain.

As computers become commoner there is little evidence that they are dramatically worse for divers. There is no firm evidence that either dive computers or tables are safer than the other.[8-12] Much the same as for cars. It is the diver misusing the diving aid that is usually at fault.

The incidence of decompression sickness reported by the BS-AC[13-16] appears to have been distributed between table and computer users in approximately the same proportions as their users over the past few years.

There is evidence that many dives can be done safely with properly used computers, giving a lower incidence of DCS than in table users diving the same dives at the same time.[17] The snag is that one cannot tell whether a table user has used it properly, while the mainly Microbrain computers used on board the *Ocean Quest* gave the dive profile which could be checked. Some have criticised this paper on the grounds that the diagnosis of DCS was made by non-medical people. Realistically most sufferers from decompression illness have the diagnosis made by another diver and later confirmed by a medico. In naval and commercial diving the confirmation often comes after treatment has started.

Advantages of dive computers

With computers some of the snags with table use are abolished.

On the whole dive computers have relatively good time and depth sensors.

Most computers turn on as the diver enters the water.

Once one knows how to use the model one is using, computers are easier to use than tables underwater. The calculations are done by the machine, not by a slightly narced and poorly trained diver, so error is reduced.

A some computers can play back the dive profile and a few allow this to be fed into a computer for permanent storage and retrieval so allowing a data base to be accumulated.

Most also display the no-stop profile available for the next dive.

Disadvantages of dive computers

Many divers have blind faith in their computers and assume that following the computer will always be a protection from DCS. This is no more true of computers than tables.

The diver has to think about the safety factors he or she wants to add because of age or physical status. These can be easily factored in with tables, but only computers which have an altitude mode, which can be used at sea level to reduce the allowable nitrogen load, allow safety factors to be added to the program. However never letting the no-stop time drop below 5 or 10 minutes adds fudge factors.

The problem with computers is the calculations done inside the computer. The longer dive is available because the computer calculates off-gassing as the diver nears the surface and so allows a longer no-stop limit. Unfortunately no one knows whether the program which is calculating nitrogen uptake and loss is correct in its assumptions. All computer users, and the users of many tables, are effectively guineapigs testing the mathematician's figures.[18] Some have come to harm as their physiology did not reproduce the physiologist's guesses. Some of the models have been altered, without much publicity, to get rid of embarrassing DCS figures.

Some of the repetitive dives allowed by some computers will quite definitely bend some people. So did some of the dives in naval tables when they were first tested in the sea after being safe in the chamber. Some dives in the USN tables are known to be less safe than the majority, and this is coped with by the Master Diver adding fudge factors of time and depth before working out the decompression requirements.

Some dive computers have fussy faces with more than one set of information being presented in the same place. If not presented clearly this can lead to problems as can having information in different places on different computers.

Some computers have been designed to stop working if the diver goes too deep or goes into decompression time. Usually the depth and time displays remain working but decompression information is not displayed. One wonders what the diver is supposed to do to get back to the surface safely if the depth and time displays have vanished. Unless he brought along a depth gauge, watch and tables, which is recommended on page 3 of the Suunto Solution instruction book (but not in the Aladin Pro, the other widely sold dive computer, manual), he or she is paddleless in the proverbial barbed wire canoe. Some computers that will bring you back to the surface refuse to work for 24 hours after a depth or decompression violation. Then they are available to the diver again but have erased all previous nitrogen loads. I wonder how many divers would do the next day's diving using borrowed tables, I am sure that some would. The Suunto Solution and one dive computer under development will return the diver to the surface after a depth or decompression violation, but will not display again until it has calculated that the diver has off gassed all of the nitrogen load.

Computers are expensive, so there is a higher profit for the dive shop in selling a computer rather than tables, which could lead to pressure to buy.

They are advertised as being safe, but with no mention of the disadvantages such as untested algorithms, shut downs and the possibility of breakdown, nor of the need to allow fudge factors. In one survey 33 out of 144 computer users had experienced a computer failure.[19] The Aladin Pro appears to have been the most reliable to date. Rumour has it that the Oceanic computers are over represented among failures.

As with tables, the computer cannot predict the wearer's physiology or physical status, nor the circumstances of the dive. There is no substantial safety margin incorporated in many decompression algorithms. Only a few more recent model computers include some safety margin buffers. On the other hand, tables require the use of "rounding up" of any intermediate depth and time and so usually allow some compensation for the body's deviation from the decompression model.

No computer available at present appears to have undergone extensive testing and most have been released without any substantial and documented controlled testing. To be blunt computer divers are guineapigs testing the safety of the computer's algorithm every dive.

For repetitive diving dive computers are generally considerably less conservative than most tables. Repetitive dives have been shown to be a significant factor in increasing decompression sickness (DCS) amongst divers, whether using tables or computers. Divers Alert Network (DAN USA) data indicate that 64% of the divers treated for DCS in the USA in 1987 had become ill after repetitive dives.[8] This increased to around 80% by 1990.[12] The increase may be due in part to divers' attempts to maximise dive time using decompression systems such as computers and the Repetitive Dive Planner (RDP).

Approximately 44% of the divers treated for DCS in the USA in 1990 had been using a dive computer.[12] It is possible that nearly 45% of American active divers used computers at that time as a 1992 survey of 265 experienced, adventurous, mostly American, divers showed that 81% used a dive computer.[20] But diver statistics are unreliable, as an active diver is often defined as one who does one dive a year. A very large study indicated that certain dive computers can be used safely if they are used intelligently and if safe diving practices are observed.[17]

At present the algorithms of most current models need to be altered to give more conservative times when the computers are used for deep repetitive dives, multi-day diving, and multi-level dives of increasing depth. Some computer manufacturers have already modified, or are currently in the process of modifying, their algorithms to try to be safer with, or discourage, such undesirable profiles.

Desirable features

I think that the ideal computer should turn itself on when the diver enters the water, show air status, depth and maximum depth, dive time, no-decompression limits for that depth, decompression status, stop depths and times and be easy to read with big numbers for aging eyes.

I would like graphics for depth, no-stop limits, with a warning zone, and air consumption.

My ideal computer should have a diver control to add fudge factors. Early in 1994 only three, including the Suunto Solution, allow the diver to select an altitude mode (a fudge factor) which reduces allowable dive times. None allow the diver to do more than this. It should be possible for the diver to add as many safety factors as he or she wants.

It should have an audible warning when a pre-selected depth is reached. No current computer does this.

It should give audible and visual warning of a rapid ascent rate and of missed decompression and allow the diver some time, say a minute, to take corrective action before entering "violation mode". This feature is available in a number of computers. When the computer registers a "violation" it should continue to display the decompression requirements for that dive before shutting down.

Its algorithm should add decompression penalties for going deep late in a dive and for repetitive dives as deep or deeper than the previous dive. It should also reduce the calculated rate of inert gas elimination if the diver yo-yos or ascends too fast, as these activities are likely to increase bubbling and so slow down gas elimination.

All dive computers should display depth, maximum depth, time underwater, remaining no-stop time and air supply in the same places on their faces. It has been suggested that this would limit innovation but standardising the position of brake, clutch and accellerator pedals in the 1920s did not slow down improvement in cars.

The computer should remember at least the last 10 dives and surface intervals. This information should be able to be accessed by a personal computer.

Conclusions

Divers must be taught the principles of how to avoid decompression illness. Some divers fail to follow the safe diving practice of doing the deepest dive first.

Both tables and computers require that the user knows how to use the aid properly. Many divers do not know how to use the tables properly.

Just as with tables divers have to understand how to use a computer. They have to read the instructions, look at the computer regularly and understand the displays of the particular computer in use.

Computers, because they require less thought, are less likely than tables to be misued when a dive profile inadvertently forces the diver to recalculate his or her remaining no-stop time underwater.

Those which integrate air consumption with the dive profile can help divers avoid running out of air.

For consideration

Given the well documented inability of many recreational divers to calculate tables properly, or maintain a predetermined depth and the lack of evidence that computer algorithms, rather than the way the computer is used, influence the DCS rate when care is taken to dive sensibly, there is a strong, if expensive, case for teaching all diving students how to usea computer rather than continue to fail to teach them how to use tables correctly.

Finally, anyone thinking of buying a computer should read Dive Computers, by Loyst, Huggins and Steidely,[21] to see which comes nearest to their ideal, before buying. A new edition will be available towards the end of 1994

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COMPUTER ASSISTED DIVING: ARE YOU IN CONTROL, OR IS THE COMPUTER?

Drew Richardson

Electronic dive computers are revolutionising recreational diving. Dive computer use has boomed from a decade ago, when it was rare to see one. Today, there are more than 16 models, and at least eight different types of dive tables. For the first time, U.S. Navy (USN) dive table use is declining and special application table and computer usage is increasing. Computers now enjoy widespread popularity amongst divers of all skill levels. The age of dive resort travel and live-aboard diving, coupled with dive computers, has established a trend towards more dives per day for several consecutive days.[1]

Dive computers are valuable tools, offering a number of advantages over standard tables. They free divers from the complexity of table calculations, and allow them to perform multi-level dives safely. Dive computers can replace both the standard timing device and the depth gauge. Since most dive computers begin timing dives and surface intervals automatically, they eliminate the hassle of using traditional timing procedures. Compared to standard analog depth gauges, dive computers are generally much more accurate and reliable. Many new dive computers provide rate of ascent information. Computer multi-level diving allows longer bottom times than those permitted by standard tables planned for one depth dives. Computers provide computerised, real-time, continuous dive profile data while under water and most importantly, the no-stop time remaining.

Used conservatively, these devices can promote safety; used aggressively, they may increase risk. Problems can arise if divers use computers incorrectly, or place complete, but unsupportable, faith in their ability to prevent decompression illness. Some individuals believe computers are infallible, and push computers to their absolute limit, over and over again. Other divers use computers without understanding their limitations. Fortunately, responsible divers understand the limitations of computers, and dive accordingly.

Divers need to understand how dive computers generate numbers, and what the limitations are, if they wish to dive conservatively assisted by a computer. Decompression decisions must still be part of pre-dive planning and post-dive information recording. The term "computer assisted diving" refers to the process of pre-dive planning, proper dive habits and post-dive follow up. A dive computer assists in making decompression decisions while underwater, however, the diver should develop and follow a dive plan that includes anticipated depth and bottom time. Let us explore a few points that help divers take control of their dives.

Decompression illness is a random occurrence

Tables and computers, no matter how well designed or how well tested, are simply mathematical models that approximate how the body absorbs and eliminates an excess of nitrogen. Avoiding decompression sickness (DCI) is a statistical phenomenon. It is impossible to design a device that is 100 percent safe, for 100 percent of the people, 100 percent of the time. Because people differ in their susceptibility to DCI (i.e. individual variations), no dive computer or table can guarantee that decompression sickness will never occur, even when diving within the table or computer limits. Divers who find this unacceptable and wish to avoid completely any risk of decompression sickness, have essentially three options:

1 Never surface from a dive.
2 Never dive in the first place.
3 Never go to altitude.

Humans are different from computers

There is a gap between computer modelling and human physiology. While decompression computers and tables spring from straight forward mathematical computation, the dynamics of nitrogen uptake and elimination within the human body do not follow these formulae. There is a wide range of variables within human physiology which affect how quickly the tissues load nitrogen to equilibrium:[2]

The blood supply of the tissues.

Solubility of the gas and the tissue relative to its solubility in blood.

Diffusion, the rate at which gas travels through the tissue.

The gradient between ambient and tissue pressures which provides the driving force for diffusion.

Temperature of the tissue. This influences gas solubility, diffusion rate and regional perfusion.

Local energy consumption, which is related to work load. This influences the partial pressure of CO_2 and regional perfusion.

The partial pressure of carbon dioxide in the tissue, which influences regional perfusion.

Unknown factors (physiological factors at play yet to be identified).

The relationship between these processes complicates the ability of a table and computer to model gas exchange effectively. The reasons are many, but include the fact that perfusion in parts of the body is intermittent. While gas elimination rates are influenced by the above processes, elimination is actually slower than gas uptake. Most decompression schedules and models, however, assume that elimination mirrors gas uptake. The majority of decompression tables and computers on the market today are based on gas uptake primarily being influenced by tissue perfusion and by the solubility of gas and tissue.[2] Exceptions are the Royal Navy, Royal Navy Physiology Laboratory (RNPL) and BSAC decompression schedules, which consider diffusion to be the rate limiting process. Most tables use a perfusion model because it is easier to calculate, and because, within limits, it reproduces the outcomes of manned tests and field data.

Mathematical calculations are further complicated by bubbles or gas phase separation. Formation of bubbles reduces the gradient for gas to diffuse out. While this complex processes is largely understood, it cannot be effectively combined into a practical, workable mathematical model. This leaves a gap between what is understood and what is effectively modelled.

Computers have operational limits

Computers are not fool proof. Environmental conditions and the random nature of recreational scuba diving can result in unexpected dives that perhaps the model and design were never intended for.

Divers compound these difficulties, and create more, by ignoring their training, their table or computer, acceptable safety rules or appropriate dive patterns. All of these variables pose problems for decompression design and schedule validation.

Multi-level diving

Multi-level diving theory is just that: a theory. Until the Powell/Rogers DSAT test established an empirical basis, little test data existed. To understand the practical and safety limits of multi-level and repetitive diving, it is helpful to have some basic understanding of mathematical decompression theory. Several excellent sources exist on this topic.[2,3]

Multi-level diving in practice is a technique for extending bottom time beyond the no-stop limit for the deepest depth of the dive profile by ascending to shallower depths. Decompression theory tracks decompression status throughout the dive by calculating nitrogen absorption and elimination in theoretical mathematical compartments. These compartments are adjusted to specific nitrogen loading limits established by the table or computer designer.

J S Haldane originally divided the body into five compartments in his work. The USN later used six compartments in the popularised version of the USN dive table. Today some dive computers and tables use 14 or more compartments. Compartments differ from one another in two ways. They each absorb and release nitrogen at different rates (half-times) as set by the designer, and they can tolerate a different maximum amount of absorbed nitrogen called “nitrogen loading.” The table designer then establishes no-stop limits through experimental test dives to establish or allow more nitrogen loading.[3]

A significant limitation of decompression theory is that it cannot account for variation in individual diver physiology, such as age, weight, gender or variation in predicted dive patterns.

What is a dive computer

A dive computer is basically an electronic calculator. All use an electronic mathematical model telling the computer what to do with depth and time information. This mathematical model or algorithm differs between brands of computers. The primary purpose of a computer is to tell a diver when he has reached a no-stop limit, so he can stay well within it. They all display depth, no-stop time remaining and elapsed bottom time.

On the whole computers are accurate depth gauges and timing devices. Tests have shown computers to be extremely accurate depth gauges being correct to within 0.3 m (one foot) at a depth of a 30 m (100 feet).[3] Some are calibrated for fresh water and read approximately three percent deeper than the actual depth when used in sea water.[3]

Dive computers have performed well when measuring time in tests.[3] One of the main advantages for the dive computer is that it knows both depth and time accurately and simultaneously.

Dive computers on the market today offer a variety of additional information in many different forms. Although dive computers come in a variety of sizes and shapes, they are all basically the same. All dive computers contain a micro-processor/computer, which is activated by a renewable power source (battery). It contains an analog to digital converter (A/D), read only memory (ROM) and random access memory (RAM) to store and calculate data and provide scrolling. All dive computers have a pressure sensor to read the depth and a timing device to read the elapsed time. This information is processed by micro-processor, using a decompression algorithm, and information is shown in the display for the diver to use.

Dive patterns

The variability of risk for decompression illness varies with the type of dive performed. The 1992 Divers Alert Network (DAN) report on Diving Accidents and Fatalities states that in 1992 slightly less than 50% of divers with a decompression illness were using computers on their dive.[4] In 1992 more than 80% of the divers who used computers and suffered decompression illness made multi-level, repetitive dives to depths greater than 24 m (80 ft).[4] Table 1 is from the DAN report and lists the factors affecting divers who used computers and suffered decompression illness from 1987 to 1992.[4] The highest incidence levels were with deep dive profiles, repetitive diving, multi-day diving, multi-level diving and divers doing dives that required staged decompression.

Differences between calculations

Tables and computers often give different numbers, which causes confusion on dive boats between user groups. The allowable bottom time sometimes varies widely for the same profile with different tables and computers. Many individuals wonder why these times vary, and controversy results. A simple explanation is that the numbers differ because of differences in the intent and design assumptions made by various table or computer designers, and because a computer mathematically interpolates precisely, while a

TABLE 1

FACTORS ASSOCIATED WITH COMPUTER DIVERS SUFFERING DECOMPRESSION ILLNESS 1987-1992

Year	1987	1988	1989	1990	1991	1992
Computer divers with DCI	n=41	n=84	n=126	n=203	n=194	n=224
Factors analysed	%	%	%	%	%	%
Repeat dive	73.2	80.5	73.0	82.3	87.4	84.4
Fatigue						35.9
Within tables	29.3	44.0	26.2	27.6	24.6	60.3
Deeper than 24 m (80 ft)	92.7	82.0	81.0	85.7	80.4	77.7
Single day	48.3	45.5	48.4	51.7	54.3	47.8
Current	43.9	42.9	44.4	52.2	47.2	47.3
Multi-day diving	51.7	54.5	51.6	47.8	45.7	52.2
Multi-level diving	56.1	58.4	68.3	67.5	80.4	91.1
Exertion	34.1	26.2	31.0	29.6	56.8	58.1
Outside tables						39.7
Decompression dive	48.8	36.9	20.6	27.1	25.1	25.9

Figures taken from reference 4.

table rounds off coarsely.

The conservatism of tables and computers, and the safety of divers using them are not one in the same. Safety is a real-world phenomenon; it is observed and measured. Safety is not determined simply by a computer or numbers in tables. If it was, the more conservative numbers would be safer, which would equal better. If this mindset was adopted to the extreme, the so-called “best table” would simply prohibit diving.

Tables and computers are not the sources of decompression knowledge, but the application of it. In determining what is best, it is important to evaluate clinical and field evidence, and to accept the fact that differences in decompression systems do not necessarily make one safe and the other unsafe.

Computer algorithms

There are concerns surrounding computer use and the lack of testing of the algorithms used. The USN tables were borrowed by the recreational diving community and performed very well, considering they were never designed for recreational diving. Recreational diving patterns have changed quite a bit in the past several years.

Exotic dive travel creates the incentive for divers to try to get their money’s worth by maximising the number of dives they do on holiday. This has resulted in multi-day repetitive diving becoming a standard practice on live-aboard boats and at many resorts.[1] Legitimate questions arise in attempting to answer the question “How much diving is too much?”[5] From a scientific standpoint very little is known about this type of diving with regard to an increased risk of decompression illness. Computers are number crunchers, not physiological monitors. They do not adjust their calculations for age, physical condition, dehydration, blood alcohol level, water temperature, strenuous diving, fatigue, etc. The diver must do that. He or she is not helped by the fact that only a few dive computers allow the user to add safety factors to the program.

Concerns over anecdotal evidence of computer using divers developing decompression illness generally arise from computer dependent diving, where there is an absence of pre-dive planning and post-dive information follow up. This type of diving shows inattention to detail, laziness or ignorance. The marvels of electronics lull some individuals into a false sense of security.

Computers increase the temptation to avoid planning scuba dives, despite the fact that dive computers will give information, in a very logical format, which conflicts with common sense and safe diving practices. For example, a dive computer will give information about the no-stop limit for a deep dive following a long shallow dive, even though doing dives in this order violates standard safe diving practices. While there is no such thing as perfectly safe diving, the question becomes, “Which behaviours reduce the incidence of decompression illness to acceptable levels?”

Good Computer Habits

Here are ten simple things to remember for developing good computer assisted diving habits.

1 The acronym, DATA, has been suggested to avoid the mistake of not monitoring instruments and gauges during a dive and to be responsible for oneself.[6] D stands for depth, a diver should know how deep he is now, and what the maximum depth was he obtained during his dive at any given time on the dive. A stands for air, a diver should know at any time on the dive how much time he has remaining. T stands for time, the diver should know how long he has been down and how much of the planned bottom time remains. A stands for area, where the diver is in relation to the exit point. This simple acronym DATA may go a long way in reminding the diver to observe the necessary parameters for computer assisted diving.

2 Divers should listen to the dive briefing and ask questions about the local dive, site and its environmental variables.

3 A diver using a computer should know how it works and remember that it is a tool. Divers should begin by reading the instructions for the model they are using. If a diver does not understand tables, he will not comprehend the significance of computer displays. Some individuals do not read the instruction manual, and this is frequently true when the computer is hired.

4 Divers should use the computer as a no decompression stops device. If a diver's bottom time is not limited by air, he should avoid pushing the computer to its no-stop limits. Running a dive computer down to zero no-stop time on each stage of a multi-level dive, or on repetitive dives, bypasses all the safety factors built into square dive calculations in tables. Divers should avoid mandatory stage decompression, slow their ascents and take a safety stop.

5 A diver needs to understand there is no such thing as perfectly safe diving, and that diving behaviour affects the risk of decompression sickness. There are still far too many cases where divers abruptly run out of air for lack of monitoring depth, time and air profiles underwater. There are nine air pressure integrated computers that predict air supply limits, in addition to no-stop limits. They have the ability to show the diver the shorter factor limiting the dive, air or no-stop limits.

6 Buddies should use their own computers and terminate the dive together following the more conservative computer in the team. They should never share a single computer.

7 Divers need to understand the display, but not accept numbers on blind faith. Rather, they should be used as a guide relative to the diver's physiology.

8 Divers need to plan dives and monitor their progress during the dive. Safe diving guidelines, such as no saw tooth diving, planning deeper dives before shallow dives, avoiding repetitive dives deeper than 30 m, need to be followed.

9 Responsible divers stay fit, drink plenty of water, sleep well, do not drink alcohol immediately before diving, do not dive when not feeling well or with an illness, and avoid strenuous exercise before, during and after diving.

10 Divers should have a back up plan in the event of computer failure.

Conclusion

Computers are valuable tools and offer a number of advantages over tables. They can replace the standard timing device and depth gauge and reduce the hassle of traditional timing devices or procedures. They can provide rate of ascent information, thus allowing divers to slow their ascents. They remove human error from calculations. They permit multi-level diving, allowing longer bottom times than those permitted by standard square wave tables. Multi-level diving with a safety stop may be less stressful, from a physiological standpoint, in the production of gas phase separation than square profiles. Computers provide computerised real-time, dive profile data while underwater and most importantly, identify the maximum no-stop time remaining.

Nevertheless, a diver's brain is perhaps the most important computer on the dive. The brain, using good common sense and a safety conscious attitude, can do more than dive computers to avoid decompression sickness.

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DEVELOPING THE DSAT DIVE COMPUTER MODEL

Ray Rogers

Summary

The modified algorithm computes conventional solutions for typical diver behaviour. It results in dive times and gas loadings similar to those of the Recreational Dive Planner. Calculated gas loadings are consistent with Institute of Applied Physiology and Medicine test data. The algorithm intervenes to restrict profiles of aggressive divers. The degree of restriction increases as diving "aggressiveness" increases.

Background

In the 1980's, the Professional Association of Diving Instructors (PADI) set out, through its corporate affiliate Diving Science and Technology (DSAT), to test decompression systems designed to replace the use of US Navy dive tables by recreational divers. Following successful tests at the Institute of Applied Physiology and Medicine (IAPM), PADI began distribution of the Recreational Dive Planner (RDP), in two formats, a circular slide rule called The Wheel™ and in a tabular format. The DSAT/IAPM research program[1] is the only significant investigation of recreational profiles, and shortly after introduction of the RDP, some of the research data were used in a number of dive computers.

Field experience of the RDP was good and interest grew in adapting the DSAT algorithm itself, not just its supporting laboratory data. DSAT was asked about the use of its algorithm, but said the program was not suitable for direct implementation in computers without extensive modification. These modifications have been made. This paper discusses the changes needed to produce the DSAT Dive Computer Model.

In testing the RDP, the study was limited to profiles allowed by the RDP, which permits only no-stop (no-stop) diving in accordance with long-standing PADI policy. Test profiles were planned to find the beginning of bubble generation while avoiding exposures that might cause decompression sickness. The tests were almost free of DCS but asymptomatic bubbles occurred as expected, suggesting that DCS might be a consequence of exposures that were appreciably more severe, i.e. for deeper or longer. A dive computer if using the identical limiting parameters as the RDP would allow greater dive time than the RDP, and might cause unacceptably high tissue nitrogen pressures. A computer based on DSAT/IAPM research should limit exposures so that compartment pressures are no greater (preferably even less) than the pressures that occurred during testing. Since it is impossible to measure pressures, a table model should be made more conservative to be used in a computer.

A primary goal of the development of the DSAT dive computer model was determination of methods which would result in dive computer profiles that are generally equivalent to DSAT Wheel profiles. Equivalence does not imply equality. Equality would be nearly impossible to achieve, and is not necessarily desirable. Equivalence implies similar gas loadings for similar exposures and further implies that bottom times would be reasonably similar for computer users and Wheel users, if a generally similar dive pattern is followed; slight deviations between the two modalities would be expected.

General description of the DSAT dive computer model

The DSAT computer model includes (among others) the following premises:

1 Haldanian theory does not explain all hyperbaric phenomena,

2 while gas overpressures are responsible for most presentations of decompression sickness, it is likely that manifestations occur with pressures thought to be tolerable,

3 the risk associated with performance of a large number of dives in a short span of time has not been adequately assessed, but when developing a decompression system, it is prudent to assume that this risk exists

A Haldane model calculates theoretical pressures in a series of tissue compartments as a diver is exposed to greater and lesser ambient pressures. Calculation results may be used to determine whether a diver may ascend directly to the surface without a decompression stop, to determine times and depths of decompression stops when needed, to monitor pressures as a diver changes depth in multi-level diving, and to calculate the amount of gas lost at the surface for determination of permissible time on a subsequent dive.

A dive computer based on the DSAT algorithm is in harmony with the philosophy and intent of DSAT and PADI. The restrictions and limitations of the RDP were founded in experience and research, and were incorporated into the computer model, in spirit if not in detail. Cautions, warnings and alerts needed to implement RDP limitations are displayed. Calculations continue even if rule violations occur, but only with visual and/or audible warning. The computer allows continued diving and does not go into error mode, but this continuation is accompanied by appropriate advice against continuing. The theoretical model is basically designed for no-stop diving and discourages intentional stage decompression diving, although the computer displays decompression information when needed.

Modified Haldanian methodology is the basis for monitoring diver status. Gas pressures are computed instantaneously for the 14 RDP theoretical compartments that manifest symmetrical, exponential on-gassing and off-gassing, and adhere to the prescribed limit values. No-stop limits are reached when compartments reach their "M-values".

The provision for safety stops at 5 m for 3 to 5 min is routine for every dive, whether the dive reached a limit or not. If a depth was to more than 30 m, an alert is displayed on later dives when depth reaches 30 m, unless there has been a surface interval of 6 hours. Alerts warn against ascent rates greater than 18 m/min. Slower rates are acceptable. Decompression stops are made at 5 m, unless compartment pressures are too great; in that case, the depth is 8 m. Decompression obligations are stringent: if a no-stop limit is exceeded by 5 min or less, the computer requires a stop at 5 m for at 8 minutes and that the diver cease diving for 6 hours. If a no-stop limit is exceeded by more than 5 minutes, the computer requires a stop at 5 m for 15 minutes (air supply permitting) and that the diver cease diving for at least 24 hours. Flying after diving notice is consistent with the latest internationally accepted guidelines.

Differences between dive tables and dive computers

Dive tables are inherently more conservative than their underlying model because:

1 depths and times are rounded off to the next greater values, and exposures are therefore not as severe as the table calculates them to be, and

2 tables calculate surface off-gassing on the basis of a single compartment, and this compartment is usually slower than the one which actually constrains a dive. Tables cannot make calculations during a dive; they are first calculated as multi-compartment models and modified to be more of a single-compartment model.

Computers do not have this problem, since they do not need to round off or depend on a single compartment.

There is another reason why tables are conservative:

3 recreational divers almost never operate at a single depth; they move freely up and down. The practice is to record the depth as the deepest point of a dive, and the average depth is usually significantly less than the greatest depth. As a result, tissue pressures are less than table determinations. This is in addition to the round-off mentioned above. A dive to a constant depth of 28 m is rounded to 30 m and a dive which was mostly between 24 and 26 m but went for a moment to 28 m, would also be rounded to 30 m.

Testing of dive tables requires use of the most severe exposures possible under the tables, and this means that all tests are at constant depths. A test of a 20 m exposure is conducted at exactly 20 m, which is very different to a dive to 20 m as done by a typical recreational diver. Laboratory tests therefore generate higher tissue pressures than table dives, and the difference is welcome, because some respected scientists think that a dive in open water (for a given time and depth) is more likely to produce decompression sickness than a chamber dive for exactly the same time and depth. Tables have a built-in margin of conservatism (they are always wrong but always conservative).

In contrast computers do not provide the same margin of conservatism; they are able to calculate the theoretical tissue pressures precisely. It is therefore necessary that computers use a slightly different mathematical basis from tables and their calculations must appear to yield lower tissue tensions than tables, which always err on the high side. This is done by programming the computer to determine pressures which seem to be lower than table determinations, so that a computer user will have gas loading similar to a table user.

These details must not obscure the fundamental goal: the development of procedures which maintain tissue pressures within acceptable levels. This is the primary purpose of all decompression systems; ideas such as M-values, no-stop limits, theoretical tissue compartments and half times are only artificial concepts that were created to serve the fundamental goal. They are useful mathematical devices which assist in the process of attempting to prevent injury from inert gas overpressure. They have no demonstrated real basis in physiology. The concepts are probably correct, but we cannot prove or disprove that they are. It probably does not even matter about physiological accuracy; what is more important is whether the ideas can be used to devise successful methods.

Adjustments to the DSAT RDP model

The most important changes in adapting the RDP model for computer use are:

1 active and unrestricted use of the entire range of theoretical compartments,

2 reduction of the M-values for all compartments,

3 progressive reduction of the surface interval credit as dive severity increases.

Active and unrestricted use of the entire range of theoretical compartments

The RDP system of Pressure Groups and surface interval credit are a function of pressure in the 60 minute half time compartment. For many repetitive dives, the RDP is unnecessarily restrictive: its operation assumes that most dives are controlled by that compartment. Because this restriction is conservative it was allowed. Modifications were made when the model was not conservative (multi-level diving and multiple long shallow dives)

These RDP adaptations result from the need to choose a single compartment on which to base the surface interval system for repetitive dives, but a computer can calculate all compartment pressures, and is free from this limitation. Fourteen compartments were used to compute the rules of the RDP. Once the calculations were completed and incorporated into the RDP, these multiple compartments had only a passive role in RDP operation. A computer designer could use these same rules, but would be giving up one of the primary advantages of computers. Using a broad range of compartments allows a computer to be free of these rules that sometimes limit a diver excessively.

Reduction of M-values for all compartments

As discussed before, computers allow more time than tables. A Wheel user who wants to dive to 30 m knows that dive time is 20 minutes. Even though the diver may move in a range of 25 to 30 m, the time is still 20 minutes. The compartment pressures would be less than if the diver stayed at 30 m the entire time; a computer would know that, and would permit a diver to remain at these depths for well over 20 minutes. A carefully determined reduction of compartment pressure limits would cause computer divers and Wheel divers to return to the surface at more nearly the same time.

Progressive reduction of the surface interval credit as dive severity increases

Performance of multiple dives in a day has been identified as a risk factor for DCS. If this type of diving continues for multiple days, the risk factor is thought to be increased. There is no convincing proof for these beliefs, but they are widely accepted. The only significant body of evidence in this area is the Phase IIb testing at IAPM, and it indicates that bubbling increases during a day but multi-day diving did not increase the amount of bubbling; these data appear to indicate that the number of single-level dives is more important.

Yet, there is anecdotal evidence that multi-day diving does cause problems, if only because multi-day divers have more opportunities for trouble; caution suggests that the question should be addressed. Accordingly, it would be prudent to restrict this type of diving by modifying the computer's program. Simple mathematical functions can progressively reduce the apparent surface interval time in certain situations. Higher risk dives become shorter when a diver is aggressive, but cautious divers are unaffected.

The combined effect of these adjustments is that average dives are calculated in a typical Haldanian fashion, but the computer intervenes to restrict aggressive divers.

Preliminary determination of M-values

M-values of the DSAT computer model are derived from a curve of no-stop limits. This curve is a variation of one described by Powell, Spencer and Rogers.[2] It uses different determinants from those of the original curve, to establish a conservative "best fit" to a series of tentative M-values which were empirically derived from a great many simulations of IAPM test profiles. The differences between the two curves result from an effort to harmonise output from static dive tables and dynamic dive computers.

The first step in developing the computer model was deciding the relationship between compartment pressures generated in IAPM tests and the M-values for the model. Extensive analysis with software written for this purpose showed that uniform reduction of DSAT Wheel M-values would serve very well, as long as the reduction was internally consistent and was based in reality. A principle called "random walk" was used to simulate the actions of divers, who seldom stay at a single level but move vertically in the water column. Random walk is a concept that says that circumstances are as likely to remain stable as to change, and that small changes are more likely than large. In modified form, it can describe a diver's movement in the water column and can be a useful tool for desktop computer simulations.

The software used inputs from either a keyboard or reading a data file. Degree of depth variation was specified (10%, 20% and 40% depth variations were examined) and the computer then simulated dives to each chosen depth for the specified time. Compartment pressures were updated every second. Summary and detailed data files were written to store the results for later use. On completing a profile, the process was repeated until a specified number of simulations were done; maxima of all simulations were averaged.

Every test profile conducted at IAPM was simulated many times. Depth variations of 0%, 10% and 20% were used for each profile (the 0% simulations corresponded exactly to actual tests). The IAPM tests were isobaric, equivalent to constant depths, and they produced higher compartment pressures than simulations to lesser depths. These higher pressures provided a useful comparison to the more conservative M-values of the model.

Accumulated data were entered into spreadsheets for a determination of the maximum calculated compartment pressures. The highest pressures generated in each compartment were considered as tentative M-values which served as starting points to generate graphs that could be examined, analysed, rationalised, and perfected. After compiling and examining simulation data and comparing the graphs that resulted from the compilations, the determination was made that the simulations which varied by 10% were sufficiently conservative, relative to isobaric simulations, without being excessively restrictive.

The next step was determining the most suitable curve of no-stop limits. The new curve needed to be more conservative than the original, requiring a rational method of adjustment. As described in Powell, Spencer and Rogers,[2] the curve is determined by three parameters: a deep exposure to its limit, a shallow exposure to its limit, and a depth at which, it is presumed, one may stay indefinitely and return safely to the surface. With addition of appropriate adjustments and modifications, a plot was created to serve as the basis for the DSAT computer model.

An aspect of the DSAT algorithm is internal consistency: all values in the model agree with each other. A curve of no-stop limits might be irregular if derived from empirical data that are irregular, but there is no need for the model to perpetuate these irregularities. This is even more important for a computer, which employs a series of separate compartments that must be coordinated, if it is to yield a smooth and "seamless" flow of information. The best way to eliminate the irregularities was to generate a series of curves by varying the three determinants and fitting the curves to the simulation data, with the goal of deriving M-values directly from the curve and inferentially from IAPM data. The criterion used for curve fitting was: new M-values must be no greater than (or less than) simulation pressures. Tentative M-values were already more conservative than the tests from which they were derived; this step added another level of conservatism.

This no-stop limit curve met desired mathematical and scientific expectations, but additional adjustments were made for the very fast and very slow compartments:

1 The DSAT algorithm has no-stop limits of 39 m (130 ft) for 12 minutes, 36 m (120 ft) for 14 minutes, and 33 m (110 ft) for 17 minutes, which were tested repeatedly during IAPM Phase I. For conservatism, these limits were later reduced slightly to 39 m (130 ft) for 10 minutes, 36 m (120 ft) for 13 minutes, and 33 m (110 ft) for 16 minutes. The pressures of the tests are therefore higher than the M-values that would produce the lower limits. The computer model M-values for the fastest compartments correspond to the pressures that would have developed with the reduced limits, not the higher pressures that actually occurred.

2 For the very slow compartments, the graph uses the maximum calculated pressures that actually developed during the IAPM tests, not the lesser amounts of the random walk variations. Compartments with very long half times are less influenced by rapid and temporary depth changes.

Progressive reduction of surface interval credit

There are many ways to impose an artificial reduction on the activity of the computer in those cases when a diver begins to "push" limits, makes several dives near limits, or both. Many alternatives were considered in search of procedures to address the possibility that slow compartments can gradually accumulate excessive pressures, even in no-stop diving. The method selected acts progressively to restrict the apparent surface interval time during over-zealous diving, resulting in an automatic reduction of time on later dives.

The restrictions operate at several levels:

1 In the calculation of off-gassing, time at the surface is multiplied by a time factor (TF), which is normally 1. If the calculated pressure in the 60 minute compartment on surfacing exceeds a defined threshold level, TF is reduced. In the first occurrence, TF is reduced from 1 to an amount less than 1, and in a later occurrence, it is reduced from its previous level. The amount of reduction depends on the degree to which the threshold level is exceeded. This mechanism reduces the calculated off-gassing during the surface interval.

2 The threshold level is decreased whenever it is exceeded, making it ever easier to initiate the reduction process.

3 If the threshold level has been exceeded previously, TF is decreased directly for each additional time that the level is exceeded.

4 These three reductions apply to all compartments equally, but an additional factor related to magnitude of half time (HT) is also used to reduce TF. This results in a non-linear limitation of the apparent surface interval. The decrement is New TF = Old TF-(HT/constant), and it magnifies the importance of slower compartments. Since the apparent compartment pressures are higher than true pressures, the combined effect of the four adjustments is both synergistic and cumulative.

5 Once the time reduction factor has been activated, it remains in effect until the diver has been at the surface for 6 hours (real time); then it is reset to unity. It is only TF that is reset: the higher-than-customary pressures remain at the last calculated levels

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This paper was prepared as a written submission for presentation at the South Pacific Underwater Medicine Society's Dive Computer Workshop in May 1994. At the time of publication the DSAT dive computer model described above has been used in the SAS DC-II, a Japanese made computer which is only available in Japan.

The address of Raymond E. Rogers, DDS, who developed the Recreational Dive Planner, is P.O. Box 759, Blairsville, Georgia 30512, USA.

ARTICLES OF INTEREST REPRINTED FROM OTHER JOURNALS

AN EPIDEMIC OF DECOMPRESSION ILLNESS

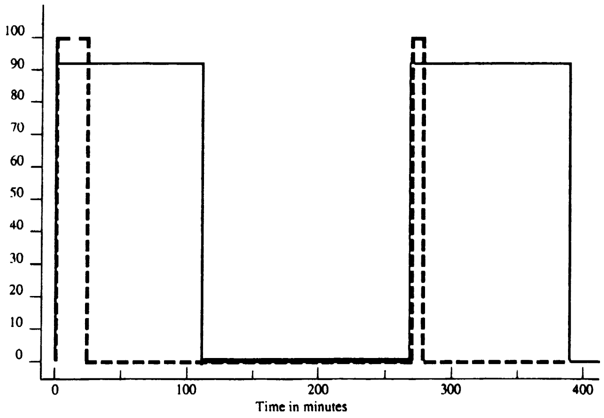
Tom Millington and Bob Izdepski

How do you treat a paralysed diver without a recompression chamber? This was the question asked of me by Dr Benno Marx several years ago. He is a family physician who runs the Clinica Evangelica Morava in Ahuas, Honduras, and he was troubled by the increasing numbers of paralysed Miskito divers who were presenting to his clinic on the Mosquito coast.

The Mosquito Coast (La Mosquitia) is the region of southern Honduras and northern Nicaragua which is on the Caribbean Sea. The coastal marshlands are spider webbed by rivers that recede into low lying rain forests and then snake up into fog whiskered mountains. To this landscape add the Mosquito Indian tribal people with their superstitions and ignorance, who are now able to bring in large amounts of money by diving for spiny lobster using scuba.

The population of La Mosquitia in Honduras is about 45,000 and about 10% of them are lobster divers. The divers are recruited in small villages and taken to the "mother boat," which is about 15 metres long. Typically there are 20 to 25 divers (buzos), none with any training. There are also 20 to 25 men who serve as paddlers for the dugout canoes from which the divers actually perform their dives.

The diving takes place in waters up to 450 km off the coast, and the trips are about 2 weeks long. The divers won't dive unless they smoke marijuana as it "helps them see the lobster better." They frequently drink rum before the dives, for the same reason.



Redrawn from Pressure March/ April 1994, page 10

Figure 1. The solid line shows the profile of a typical Miskito daily dive (From a recording made with a Suunto dive computer, courtesy of Richard Dunford). This diver used 4 tanks on each of the two dives, surfacing for less than 6 minutes, bottom to bottom, for each change, as the tank change profiles do not show on the printout. Dotted lines show allowable time using USN no-stop tables, with same surface interval (165 minutes) for comparison.

The canoe leaves the mother boat with the diver, paddler, and 3 or 4 tanks. The diver descends directly to depths of 35 m (120 feet) and deeper (as the resource has been fished out shallower), hooks as many lobster as he can hold, and then ascends directly to the canoe when he is out of air or cannot hold any more lobster. Here he switches tanks and directly descends to depth to continue fishing. They dive a minimum of 8 to a maximum of 20 tanks a day, with bottom times of about 30 minutes, and surface intervals of probably less than 2 or 3 minutes, but surely less than 6 (since they do not show on the Suunto profile, which stores the deepest point every three minutes, in Figure l).

They have pain in their joints by the end of the second dive, which they think is normal. They believe that they develop “la enfennidad de buzos,” or neurological DCI, from a mermaid casting a spell on them.

A survey of 54 divers by the Ministry of Health revealed that 49 out of 54 divers questioned had symptoms of DCI. Note that none of them were actually examined by trained medical personnel. We believe that a good neurological exam would find a 100% incidence of abnormalities. In the last 3 months alone there have been at least 10 diving fatalities along the coast, probably more since communication is by word of mouth. The average rate seems to be about 3 deaths a month.

Of course those that survive but are paralysed usually die within 3 to 4 years from sepsis secondary to urinary tract infections or infected decubitus ulcers (bedsores).

Due to the request for help from Dr Marx, an old Vickers hyperbaric chamber was donated to the clinic in Ahuas by Los Roblos Regional Medical Center in Thousand Oaks, California. This has been used by Dr Marx in treating close to 100 divers since August of 1991. The chamber is only rated for 2 atm gauge, so the divers are getting twice a day 2 hour treatments, at about 2.4 atm abs. Dr Marx is pushing the chamber a little. The first 60 divers treated ranged in age from 17 to 50, with the depths of their accident averaging about 35 msw (110 fsw). 30% of them presented with bilateral leg paralysis, with the next most common presentation being a hemiplegia. The average delay to treatment was 5 days, with a range from 1 day to 2 weeks. The divers frequently seek treatment with a witch doctor first, to cast off the spell of the mermaid!

Of the first 60 cases treated, there was 1 death, attributed to cerebral bends. There were 33 severe cases, 19 moderate, and 7 mild cases. There was 1 diver who had limb pain only.

The results of treatment in the chamber were complete recovery in 24 cases, good recovery in 16 cases, fair response in 14, and no recovery in 6 cases.

There have been days where Dr Marx has had 4 or 5 paralysed divers lined up in the clinic for treatment. He is hoping that a multiplace chamber can be found for the clinic so that he can treat more divers at one time, as well as use proper treatment tables.

Additional hope for the divers is the opening up of a school to train them properly. A commercial diver from New Orleans, Bob Armington, has felt the call to help these people, and has opened up a small school in a village called Cocobillia. He started with his own money, and is receiving a monthly donation of $100 from the Moravian Church to help. They need instruction in the use of depth meters, watches, dive tables, etc.; they need this equipment also. He recently graduated his first class of 10 proud “professional” divers.

These dedicated volunteers desperately need your help. The decompression problems that have plagued these indigenous Indian divers through the 80’s have grown exponentially in the 90’s. Deeper waters are being fished now, since the shallows have been depleted of lobster. This is the moral Armageddon of diving!

The Working Diver Magazine is now funnelling donations of equipment and cash (make checks payable to *The Working Diver* Trust Fund) into the solution of these medical and educational problems. There is also a rare opportunity here for decompression field studies while helping the Miskitos. Contact Bob Izdepski, Editor/Publisher of *The Working Diver Magazine,* P.O. Box 834, Lacomb, Louisiana, 70445. Telephone from outside U.S.A. 1-504-6499515; Fax 1-504-649-9518.

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J Bob Izdepski is a commercial diver turned Editor/ Publisher, of The Working Diver Magazine.

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DIVING MEDICAL CENTRE
SCUBA DIVING MEDICAL EXAMINATIONS

Three day (long weekend) courses are conducted to instruct medical practitioners in diving medicine, sufficient to meet the Queensland Government requirements for **recreational** scuba diver assessment.

The next courses will be at the
Royal Perth Hospital, Perth, Western Australia, on 14th-16th April 1995 (Easter)
Bond University, Gold Coast, Queensland on 29th April-1st May 1995 (Labour Day Weekend Queensland)
Royal North Shore Hospital, Sydney, New South Wales, on 30th September-2nd October 1995 (Labour Day Weekend N.S.W.)
Hamilton Island, Queensland on 14th-16th October 1995

DIVING MEDICINE UPDATE ’95
(in association with the Hyperbaric Treatment Center, University of Hawaii)
Honolulu, Hawaii, U.S.A. 20th-26th May 1995
For further details contact
Dr Bob Thomas, Diving Medical Centre, 132 Yallambee Road, Jindalee, Queensland 4047.
Telephone (07) 376 1056 / 1414

FREMANTLE HOSPITAL HYPERBARIC UNIT COURSE ON DIVER MEDICAL ASSESSMENT

Date	24th-26th March 1995
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Cost	$500.00

A deposit of $ 100.00 is required to reserve a place.

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Phone	(09) 431 2233
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Unit 1	St John Ambulance Occupational First Aid Course.	Cost approximately $A 500
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Dates

February 1995

Unit 1	13/2/95	to	17/2/95
Unit 2	20/2/95	to	24/2/95
Unit 3	13/2/95	to	3/3/95

July 1995

Unit 1	3/7/95	to	7/7/95
Unit 2	10/7/95	to	14/7/95
Unit 3	3/7/95	to	21/7/95

November/December 1995
Dates to be fixed

Diver Medical Technician Refresher Courses

Dates
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Cost $A 350

For further information or to enrol contact

Dr John Williamson, Director, HMU,
Royal Adelaide Hospital, North Terrace
South Australia, 5000.

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FIT TO DIVE 1995
"HAZARDS TO HEALTH"

A major recommendation of the 1994 Edinburgh "Fit to Dive" meeting was that prescriptive pass/fail standards of fitness to dive should, wherever possible, be replaced by a greater emphasis upon the assessment of each individual diver. The essential foundation for any assessment of a diver is a detailed knowledge of the hazards to health and safety at the diver's workplace. Professor David Elliott and Dr Nick McIver will describe these. They will review the diver's tasks, his working environment, the equipment that he has to use and the diving rules and emergency procedures that need to be followed. There will also be a detailed review of the clinical aspects, including management of barotrauma, in-water loss of consciousness and acute decompression illness, which are needed for an assessment of fitness to return to diving.

There will be two weekends available for this course. **7th-9th April 1995** at the Atlantic Hotel, La Moye, St Brelade, Jersey, Channel Islands and **12th-14th May 1995** at the Viking Hotel, North Street, York, England.

For further details contact
Biomedical Seminars, 7 Lyncroft Gardens, Ewell, Epsom,
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ROYAL ADELAIDE HOSPITAL HYPERBARIC MEDICINE UNIT

Basic Course in Diving Medicine

Content	Concentrates on the assessment of fitness of candidates for diving. HSE-approved course
Dates	Monday February 27th to Friday March 3rd 1995 Monday July 17th to Friday 21st 1995 Dates to be fixed November or December 1995
Cost	$A 500.00

Advanced Course in Diving and Hyperbaric Medicine

Content	Discusses the diving-related, and other emergency indications for hyperbaric therapy.
Dates	Monday March 6th to Friday 10th 1995 Dates to be fixed November or December 1995
Cost	$A 500.00
	$A 800.00 for both courses

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