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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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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: 17-23

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Information may be sent (in confidence) to:
Dr D. Walker
P.O. Box 120, Narrabeen, N.S.W. 2101.

EDITORIAL

The Editor's offering

This journal contains a number of interesting papers. Perhaps that which affects members most closely is Mr Terry Cummins' honest appraisal of the Diver Emergency Service (DES) and the medical profession as seen from the diving instructor organizations' point of view. Some might consider that paranoia shines through this window into the diver training soul. We take a kinder view and attribute his views to lack of knowledge about another profession. Following Mr Cummins' paper is Dr David Davies' reply to the points raised. This is an attempt to make known to the diving community the actualities of DES (soon to be known as DAN Australia) and the medical view of what needs to be done to improve diving safety. We hope that this frank interchange of views will lead to harmony among instructors and diving doctors. Once again much of the misunderstanding seems to have come from the erroneous belief that any well known diving doctor is voicing SPUMS policy when he makes any comment. This is not so. **The only people who speak for SPUMS are the President and the Secretary.** On occasions another member of SPUMS may be nominated to speak on behalf of the Society on a special topic as Dr John Knight was during the preparation of AS 4005.1 1992 and Dr David Davies preparing the SPUMS statement on Diabetes, published in the last issue of the Journal

The paper from the Townsville Hyperbaric Unit shows the usual association of decompression illness with inexperienced divers. But it brings to the fore the risks to divemasters and instructors, who do multiple ascents in the course of their work. It is becoming clear that even the warm water of North Queensland does not protect divers from dive patterns which increase the risk of decompression illness.

Brian Hills has produced another lateral thinking paper. The many reports of one diver being afflicted and his buddy being undamaged after a less than perfect decompression has always been explained on the basis of individual variation. But so far no one has produced any explanation for this phenomenon, other than the production of fewer bubbles. This "explanation" is obvious enough but the underlying reason has not been found. Perhaps Professor Hills is right, as he was with his study of why Torres Strait divers did not get as much decompression sickness as the experts expected. He was able to show that their deep first stops gave much more efficient gas elimination pattern than the USN's much shallower first stops. His thermodynamic theory of decompression is still the most logical theory and with the fewest problems.

David Brookman's electronic doodlings led him to see how to produce tables and graphs showing on- and off-gassing and air consumption during dives. The paper has been published to encourage other computer users to try their hand at understanding how the calculations that make up the tables, and which dive computers carry out, are arrived at. Readers may remember Ray Rogers' paper on the development of the PADI wheel. He started using a computer to calculate USN decompression tables and then altered some of the parameters to come up with his own table. Whether this was a good idea or not depends on ones viewpoint. But using one's brain to understand difficult concepts has everything to recommend it.

We must apologise to Bob Halstead for a typographical error which changed the whole meaning of the title of his paper published in the last issue. We hear again from him on High Tech Diving in the Letters to the Editor. Dr Botheroyd of the UK Health and Safety Executive writes about their decision to abandon routine long bone surveys. With better decompression procedures, developed over relatively recent years, the incidence of new cases of dysbaric osteonecrosis has dropped to a point where there is little to be gained from routine X-rays.

Allan Sutherland's two letters, one about a pool training air embolism and the other about lasting cerebral sequelae, are food for thought. Is it only advancing age, and perhaps a long standing consumption of alcohol, which makes many divers a little forgetful and gives them hearing problems ? On the face of it there could be a case for multiple small cerebral infarcts causing these soft neurological changes. Here is a research project for someone. But who in the diving industry would be willing to fund such a study ?

There is not much altitude diving done in Australia, but our readers are not all in Australia and many live in countries with high lakes. The Cross corrections for altitude have been used for many years. A more conservative correction should be safer, which is why we have reprinted a, slightly altered, paper, by Bruce Wienke and Dennis Graver, from the NAUI magazine SOURCES.

Glen Egstrom's two papers are revised transcripts of his lectures. They are not as good to read as his lectures were to watch and listen to, as we cannot reproduce his slides. But much editorial effort has gone into trying to distil the essence of his presentations. We hope that we have not done him an injustice. Drew Richardson and Karl Shreeves write about recreational multi-day diving operations, mostly in the Caribbean, with a gratifyingly low incidence of decompression illness.

Finally there is a section on decompression illness in the form of abstracts from the 1991 Annual Scientific Meeting of the Undersea and Hyperbaric Medical Society.

ORIGINAL PAPERS

50 DIVERS WITH DYSBARIC ILLNESS SEEN AT TOWNSVILLE GENERAL HOSPITAL DURING 1990

Robyn Walker

Abstract

This paper reviews the presentation, treatment and outcome of 50 consecutive divers presenting to the Townsville General Hospital with a dysbaric illness during 1990. Inexperience, repetitive diving and multiple ascents were identified as predisposing factors to dysbaric illness.

Introduction

Recreational scuba diving has become one of Australia's growth industries. There are no reliable estimates of active divers within Australia, however PADI Australia certified their 200,000th diver during November 1990.[1] However this growth in popularity has been accompanied by an increase in the number of divers treated by hyperbaric facilities. PROJECT S.A.F.E.R. divers[2] reported a total of 228 Australian divers treated for decompression sickness in 1989 compared to 126 with 1986.

This paper reviews the presentation, treatment and outcome of fifty consecutive divers with decompression illness presenting to the Townsville General Hospital Hyperbaric Medicine Unit during the period from 1st January 1990 to the 25th November 1990. This unit accepts patients from Queensland, Papua New Guinea and the South Pacific Island nations.

Treatment

Recompression, when indicated, was performed in either a twin lock Comex deck recompression chamber housed at the Townsville General Hospital (on permanent loan from The Australian Institute of Marine Science) or in a two man Dräger Duocom portable chamber whilst en route to the main facility in Townsville. The Duocom chamber is supplied and operated by The North Queensland Emergency Response Group (NQERG) which formed following the demise of The National Safety Council of Australia (Victorian Division) in March 1989. NQERG also provide a Beechcraft Super King Air (fixed wing) aircraft or a Bell 412 helicopter, both are capable of transporting the portable chamber. The static facility is equipped with a female NAT0 N1079 flange which permits transfer under pressure (TUP) from the portable recompression chamber. During this period there were 40 divers treated for decompression sickness (DCS) and 10 divers were referred with a provisional diagnosis of cerebral arterial gas embolism (CAGE). A diagnosis of CAGE was confirmed in six of these cases. A detailed breakdown of these 50 cases is presented.

Cases

Twenty five males and 15 females presented with the diagnosis of DCS and 6 males and 4 females with suspected CAGE. The ultimate diagnoses in the latter were CAGE in 6 and near drowning in 4. One of the 4 had an epileptic fit while the others panicked. Table 1 gives the age group of the patients.

TABLE 1

AGE DISTRIBUTION

Age	DCS		CAGE	
	Cases	%	Cases	%
15-20	2	5	2	20
21-25	15	37.5	5	50
26-30	12	30	2	20
31-35	4	10		
36-40	1	2.5		
41-45	3	7.5		
46-50	1	2.5	1	10
> 50	2		5	
Total	**40**		**10**	

Just over a quarter of those with DCS were under instruction, as were 60% of those with the initial diagnosis of CAGE. (Table 2).

TABLE 2

QUALIFICATION LEVEL

	DCS		CAGE	
	Cases	%	Cases	%
Student undergoing training	10	25	5	50
Open water certification	7	17.5	2	20
Advanced course student	1	2.5	1	10
Advanced certification	4	10	-	-
Divemaster certification	3	7.5	-	-
Instructor certification	8	20	1	10
Military	1	2.5	-	-
Unknown	6	15	1	10
Total	**40**		**10**	

The divers were assessed for experience. Over 40% of the DCS cases had done less than 20 dives. For the CAGE presentation the figure was 80%. (Table 3).

TABLE 3

DIVERS EXPERIENCE

	DCS		CAGE	
	Cases	%	Cases	%
Student undergoing training	10	25	5	50
Novice diver (<20 dives)	7	17.5	3	30
Occasional diver (eg once a year holiday)	5	12.5	-	-
Regular diver (>10 dive days/year)	3	7.5	-	-
Experienced diver (years of experience)	12	30	2	20
Unkown	3	7.5	-	-
Total 40		**10**		

Table 4 identifies North Queensland, in particular Cairns, Port Douglas and Townsville, as the major sources of referrals.

TABLE 4

GEOGRAPHICAL LOCATION OF INCIDENTS LEADING TO REFERRAL

	DCS		CAGE	
	Cases	%	Cases	%
Townsville	13	32.5	2	20
Cairns	13	32.5	4	40
Airlie Beach	4	10	2	20
Papua New Guinea	4	10	1	10
Brisbane/Gold Coast	3	7.5	-	-
Mossman/Port Douglas	2	5	-	-
Rockhampton	1	2.5	-	-
Fiji	-	-	1	10
Total	**40**		**10**	

In this series over 70% of divers with decompression sickness and 90% of divers presenting as CAGE were aged 30 years or less. This correlates with figures estimating that the majority of people being trained as sports divers in Australia are men aged between 19 and 35 years.[3]

It is of great concern that 27.5% of the divers treated for DCS and 50% of CAGE victims were participating in basic certification courses under the direct supervision of a qualified diving instructor. Most divers reported average depths of no greater than 15 m on any one dive. However, the students often completed nine to ten dives within a three day period. Inexperience is a major predisposing factor with 42.5% of the cases of DCS occurring in divers who had undertaken less than 20 dives. Similarly 80% of the divers referred with CAGE were novices.

Eight full time diving instructors were treated for decompression sickness (Table 2) and in all eight cases the practice of performing multiple ascents whilst engaged in conducting an open water course was identified as a contributing factor to their illness. These figures suggest that the practice of instructors escorting each student during emergency swimming and alternate air source ascents exposes the instructor to an increased risk of dysbaric illness.

Retrievals

The Dräger Duocom was used for 13 retrievals (8 DCS, 5 CAGE) while a further 4 patients were air transported with a sea level cabin pressure (3 DCS, 1 CAGE). Long distance retrievals require detailed planning. Air and oxygen requirements must be calculated accurately, and the relative lack of environmental control within the portable chamber creates difficulties in maintaining the fluid status of both patient and attendant, particularly in tropical climates.

It is this unit's policy not to use the Duocom chamber to transport a critically ill, ventilated patient suffering from CAGE. The confined space within the Duocom, combined with the lack of monitoring and mechanical ventilation capabilities, means the prolonged treatment of such a patient is less than ideal, notwithstanding the need for urgent recompression. Such patients are transported to Townsville in an aircraft capable of achieving and maintaining sea level cabin pressure.

Repetitive diving

Repetitive diving is the major contributing factor to the development of DCS in this group of divers. Table 5 gives the pattern of diving of those diagnosed as having DCS. All divers did at least 2 dives a day and up to 5 a day were recorded. In general the divers were unaware of the risk of multiple exposures to an increased ambient pressure. The Queensland Workplace and Safety Regulations[4] state a diver must not participate in any more than four dives in any 24 hour period, midnight to midnight on the same day. However it is a regular practice for divers to perform four dives within a six hour period, particularly on the final day of an extended trip. This trend for minimal surface intervals should be actively discouraged.

Decompression tables

Table 6 lists the decompression tables used by the individual divers. No inferences can be drawn from these figures as the total number of divers using any table is not

TABLE 5

DIVING PATTERNS
DECOMPRESSION SICKNESS CASES

	Cases	%
Single days diving	12	30
Two day dive trip	13	32.5
Three day dive trip	8	20
Four day dive trip	1	2.5
Seven day dive trip	3	7.5
Extended diving	3	7.5
Total	**40**	

The number of dives per day ranged from 2 to 5.

TABLE 6

TABLES USED
DECOMPRESSION SICKNESS CASES

	Cases	%
PADI recreational dive planner	22	55
Dive computer	5	12.5
PADI wheel	1	2.5
SSI tables	1	2.5
NAUI tables	2	5
USN tables	2	5
None	1	2.5
Unknown	6	15
Total	**40**	

known. PADI certifies the majority of Australian divers and so their tables can be expected to be used by the majority of divers.

The Queensland Workplace Health and Safety Regulations also state all dives performed within Queensland are to be planned as no-stop dives and conducted in accordance with dive tables as specified in the Australian Standard AS 2299.[6] This standard lists the following examples of tables currently acceptable; tables in use by the Royal Australian Navy (RAN), the Royal Navy (RN), the United States Navy (USN) and the Canadian Defence and Civil Institute of Environmental Medicine (DCIEM). Every diver treated for DCS attested his or her dives were within a particular table's limits. But only in 13 cases (32.5%) were the profiles within the limits of the DCIEM tables. Dive profiles were not recorded in the hospital notes, or not logged by the diver, in 6 (15%) of cases.

Other factors

In 20 (50%) of the divers, no contributing factors were identified. Nine divers, 8 of them full time diving instructors, who presented with DCS had done multiple ascents. This was the largest group when a contributing factor was identified. In 6 divers, seasickness or nausea was thought to have contributed, while 3 were obese and 4 had been drinking alcohol. Some of these divers had more than one contributing factor, so there were only 11 divers affected by these three conditions.

Predisposing factors that have been cited in the development of CAGE resulting from pulmonary barotrauma include inadequate exhalation, uncontrolled buoyant ascents and underlying lung pathology (cysts and bullae).[7] None of our patients with a definitive diagnosis of CAGE had any such identifiable risk factor. All had normal chest X-rays. None were asthmatic. All who arrived at the surface unaided had performed controlled ascents. This suggests the occurrence of localised air trapping, as opposed to a generalised overpressure injury, is an important cause of CAGE.

Presenting symptoms

Joint pain and sensory disturbance were the most often described symptoms in divers presenting with DCS. All patients had more than one presenting symptom (Table 7). Generalised fatigue, poor concentration and abnormalities of higher mental functions were frequently seen.

Ten divers were referred with the provisional diagnosis of CAGE. (Table 8). Five (50%) presented with loss of consciousness however 3 were not due to CAGE. One student who was found convulsing and unconscious in the water was later able to inform his rescuers that he was an epileptic, but not before an expensive retrieval and therapeu-

TABLE 7

PRESENTING SYMPTOMS
DECOMPRESSION SICKNESS

	Number	%
Joint pain	30	75
Paraesthesia/anaesthesia	22	55
Fatigue/lethargy	15	37.5
Headache	8	20
Unsteady gait	8	20
Dizzyness.lightheadeness	7	17.5
Weakness	5	12.5
Nausea	3	7.5
Urinary retention	1	2.5
Total presenting symptoms	99	247
Total patients	40	100

All patients had more than one symptom

TABLE 8

MAJOR PRESENTING SYMPTOMS (CAGE)

	Presumptive		Confirmed	
	Cases	%	Cases	%
Loss of comsciousness	5	50	2	20
Weakness	2	20	2	20
Sensory	2	20	1	10
Bilateral visual loss	1	10	1	10
Total	**10**		**6**	

tic recompression had been performed. He had denied epilepsy during his diving medical examination. One novice diver and one resort course student both panicked at depth, losing their air supply. Both were "found" unconscious in the water. The resort course student, having received minimal instruction, had been left alone at depth while the instructor surfaced. This practice cannot be condoned. Another patient, who presented with sensory loss, was a novice diver undergoing a refresher course. She had been certified in another country, despite her history of panic attacks requiring specialist medical attention. She panicked in the water. Her ascent to the surface was slowed by an instructor. Immediately on surfacing she experienced the onset of generalised paraesthesiae and difficulty in walking. Examination was unremarkable. The treatment of this diver was difficult due to her mental state. Her history was inconsistent, her symptoms altering and a trial of recompression was of no benefit. The ultimate diagnosis was not felt to be CAGE. However she was advised she was permanently unfit to dive due to her psychological instability.

Six confirmed cases of CAGE were treated. One occurred in a swimming pool during the first training session.[8] Despite an early recompression a left hemiparesis was the final result. The outcome was similarly poor in an instructor who embolised, was retrieved from the water unconscious and after delayed recompression had evidence of an incomplete spinal cord lesion at the level of T6.

Delay in seeking treatment

In 60% of cases of DCS initial contact with the Hyperbaric Unit was not made for at least 24 hours after the development of symptoms. (Table 9). Most of the divers related their symptoms to anything but an exposure to increased atmospheric pressure. Typically notification of CAGE occurred early, the delay of 60 hours related to an incident in Fiji.

Our time from notification of a problem until recompression (Table 10) is acceptable considering the distances involved. Road transfers from Cairns involve a travel time of between four to five hours. Flying time to Brisbane or Port Moresby is approximately three and a half hours in the Beechcraft Super King Air.

TABLE 9

TIME FROM ONSET OF SYMPTOMS TO NOTIFICATION

Decompression sickness

	Cases	%
Less than 3 hours	5	12.5
3 to 6 hours	7	17.5
6 to 12 hours	3	7.5
12 to 24 hours	9	22.5
24 to 48 hours	2	5
48 to 72 hours	3	7.5
72 to 96 hours	3	7.5
Over 96 hours	7	17.5
Unknown	1	2.5
Total	**40**	**100**

CAGE

	Cases	%
Less than 30 minutes	4	40
30 to 60 minutes	1	10
1 to 2 hours	1	10
Over 8 hours	1	10
Over 24 hours	1	10
Over 60 hours	1	10
Unknown	1	10
Total	**10**	**100**

TABLE 10

TIME FROM NOTIFICATION TO RECOMPRESSION

	DCS		CAGE	
	Cases	%	Cases	%
Less than1 hour	-	-	1	10
1 to 3 hours	13	32.5	1	10
3 to 6 hours	7	17.5	4	40
6 to 9 hours	6	15	-	-
9 to 12 hours	3	7.5	1	10
12 to 24 hours	10	25	1	10
Unknown	1	2.5	-	-
Not recompressed	-	-	2	20
Total	**40**		**10**	

Treatment

Initial treatment in all except one case was an RN Table 62. In 17 cases (34%) this was extended. Two presumptive CAGE cases were not treated and one had an 18 m soak. In recent times we have acquired the necessary equipment for the delivery of mixed gases (e.g. heliox) which will expand our therapeutic options in the more difficult case.

Thirty nine patients were given between 1 and 10 follow up soaks for residual symptoms. (Table 11). These repeat treatments were continued for as long as definite improvement of symptoms or signs occurred.

Treatment results

TABLE 11

FOLLOW UP OXYGEN SOAKS

	DCS		CAGE	
Soaks	Cases	%	Cases	%
0	512.5	6	60	
1	14	35	1	10
2	7	17.5	2	20
3	5	12.5	-	-
4	3	7.5	-	-
5	2	5	-	
6	1	2.5	-	-
7	3	7.5	-	-
10	-	-	1	10
Total	**40**		**10**	

The majority of our cases (26 DCS and 4 CAGE) were asymptomatic after treatment. Thirteen DCS cases were left with mild impairment after treatment. A 19 year old female with DCS has a severe residual proprioceptive deficit and 4/5 weakness of her right leg. Two CAGE victims with severe residual impairment have been mentioned earlier.

The success of our treatment should be measured in terms of outcome and the presence of residual fixed deficits.

Conclusions

In this review inexperience, repetitive diving and multiple ascents were identified as predisposing factors for decompression illness. In my opinion it is inexcusable to have students developing DCS during their certification course. The instructor agencies have the responsibility of fulling informing their students of the risks of repetitive diving and of stressing that any exposure to increased ambient pressure may produce a dysbaric illness. They should also emphasize that the issue of a certification card does not equate with expertise.

All divers should be fully conversant with the symptoms and signs of the decompression illnesses and be aware of the need to obtain medical advice early. Delays in seeking treatment can result in permanent physical sequelae.

It must be stated that no computer or decompression table is infallible and divers should exercise caution and dive well within the no-stop time limits for any depth. It is also wise to have a rest day in the middle of an extended diving expedition to facilitate the off-gassing of nitrogen from slow tissues.

Fifty cases are insufficient to draw significant conclusions regarding the reliability of decompression schedules or the correct treatment table. However if all Hyperbaric Units in Australia report such information it can be collated and used to further diving safety in this country.

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Dr R M Walker was Locum Director of Hyperbaric Medicine at Townsville General Hospital when this paper was written.

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SPINAL DECOMPRESSION SICKNESS: THE OCCURRENCE OF LAMELLAR BODIES IN SPINAL TISSUE AS POTENTIAL FOCI FOR BUBBLE FORMATION

Brian Hills

Abstract

A novel fixation method designed specifically to preserve lamellated phospholipid structures has been used to demonstrate lamellar bodies in the spinal tissue of sheep by transmission electron microscopy. The extreme surface activity long associated with these structures in the lung would make them prime agents for initiating bubble formation. Hence their widely differing incidence and distribution within sections, between sections and between subjects indicates that they could be a major factor in determining individual susceptibility to spinal decompression sickness.

Introduction

Spinal manifestations of inadequate decompression of divers are not only more likely to occur that other forms of neurological decompression sickness (DCS)[1] but are also more likely to result in residual injury. While the pathology of spinal DCS is well documented[2-4], the basic mechanisms whereby the separation of gas from solution can give rise to these potentially debilitating lesions remains a most important yet controversial issue.

The fact that only 2% of blood flow to the central nervous system goes to the spinal cord[5] has been put forward[6,7] as strong evidence against any mechanism based upon arterial embolism. At least, this assumes that embolism is synonymous with infarction, which may not be the case in view of recent evidence of the ability of arterial bubbles to pass through brain tissue[8]. Whether justified or not, the search for mechanisms beyond arterial embolism led to the theory of venous occlusion at the level of vertebral venous lakes[6]. This theory and others invoking infarction were disputed on several grounds, one being the experience that spinal symptoms are not only reversed by recompression but are repeatedly pressure-reversible[7]. Since recompression has been observed to dislodge bubbles occluding blood vessels[9], it is hard to envisage a subsequent decompression causing another shower of intravascular bubbles to lodge or form in the same sites, at least, not to the extent that the symptoms and their distribution are identical to those caused by the initial decompression. Such arguments would favour location the offending gas in extravascular sites in which fixed position the same gas could repeatedly reverse the same symptom distribution simply by compromising and restoring local blood flow as its volume changed in accordance with the decompression/recompression protocol being followed. Mechanical studies of the spinal cord[7] proved compatible with this mechanical approach to spinal DCS but still leaves open two vital questions. The first is why spinal tissue should be so prone to bubble formation upon decompression, while the second concerns why certain individuals should be more susceptible than others.

There are the obvious factors predisposing the spinal cord to bubble formation such as the higher degree of gas supersaturation which would arise upon decompression in any tissue with a relatively low blood perfusion rate. Then there is the high lipid content, especially where white matter exceeds grey. In the original studies of Haldane's group[10] their counts of bubbles in the cords of goats at different vertebrae correlated well with the white:grey ratio. However there would still appear to be some other factor which causes some spinal sites in some individuals to be so much more conducive to bubble formation than others.

Turning to basic physics, Yount[11,12] has emphasized how surfactants can stabilise bubbles and preserve macronuclei, pointing out how surface-active phospholipid (SAPL) is present in vivo. SAPL is the predominant and most active ingredient in the mixture of saturated phoshatidylcholine, other phospholidpids, unique proteins and other minor components simply known as "surfactant" in the lung.[13] In this organ, SAPL it has long been studied for its surface activity which is very high by comparison with many surfactants studied in the physical sciences.[14] Its ability to reduce the surface tension of the air-aqueous interface is not only thermodynamic but also kinetic. The alveolar Type II cell produces "surfactant" in truly remarkable "packages" known as lamellar bodies (LBs)[15] from which the highly active SAPL is instantly recruited to the interface as they "pop to the surface".[16] These lamellar bodies would thus be particularly conducive to initiating bubble formation upon decompression of a tissue or stabilising bubbles or their nuclei upon compression.

Upon decompression, LBs should pose no problem in the lung where there is never any significant supersaturation of gases due to virtual equilibration of parenchymal tissue with the environment. In other tissues, however, their presence during decompression could be much more serious. In recent studies in this laboratory of novel roles for surfactant, we have found LBs in parietal cells from which their secretion could enable SAPL could provide the gastric mucosal barrier[17,18] and in synovial fluid in which SAPL could provide the elusive load-bearing lubricant of the joints.[19,20] Moreover, in a review[14] of the morphological literature of other organs, lamellated shapes strongly resembling LBs can often be seen in electronmicrographs which the authors ignore or, occasionally in passing, describe them simply as "whorls" to which they attribute no functional significance.

This study was designed to determine whether there are any lamellar bodies in spinal tissue. A secondary reason was to search for any vascular lining of oligolamellar SAPL which we have recently demonstrated in brain[21] where it is conceivable that it could be providing the blood-brain barrier, a barrier long known to be opened by any circulating bubbles.[22,23]

Materials and method

MATERIALS

The source of spinal cord was three healthy 4 year old sheep killed by stunning with a captive-bolt gun followed by exsanguination. Within 15 minutes of death transverse sections of the spinal cord were excised at levels T4 and L1 and placed in the primary fixative in preparation for transmission electron microscopy. These locations were selected as the two vertebrae most commonly implicated for spinal DCS in man[24], although not necessarily the most vulnerable in sheep.

FIXATION

Standard fixation procedures based upon glutaraldehyde[25] are the worst for preserving lamellated phospolipid since surfaces which they coat are often hydrophobic[14,17,20] and aldehydes, especially glutaraldehyde, are known to destroy hydrophobic surfaces.[26] In this study glutaraldehyde was reduced to 2% by substituting tannic acid (3%) shown to be ideal for visualizing oligolamellar phospholipid and used so effectively for demonstrating such structures in the lung.[28] The fixative was buffered to a pH of 7.4 with 0.1 M sodium cacodylate at 4 °C and rendered isotonic with CSF from the same cord by adding NaCl. Special attention was paid to isotonicity to avoid 'peeling' of any hydrophobic lining as described elsewhere.[14]

Another major departure from standard procedures was a very long (72 hours) fixation time based upon the simple reasoning[18,21] that barriers such as the blood-brain barrier are characterised by their impermeability to water-soluble solutes and this category includes fixatives. Post-fixation was effected with 1% osmium tetroxide buffered at a pH of 7.4 with embedding in resin (Spurr mix 'A'; Probing & Structure, Kirwan, Queensland) polymerised at 60 °C. Emphasis was placed upon cutting very thin (<60 nm) sections with a very sharp diamond knife in order to resolve lamellated structures. For comparison purposes two blocks were fixed from cerebral cortex of one sheep.

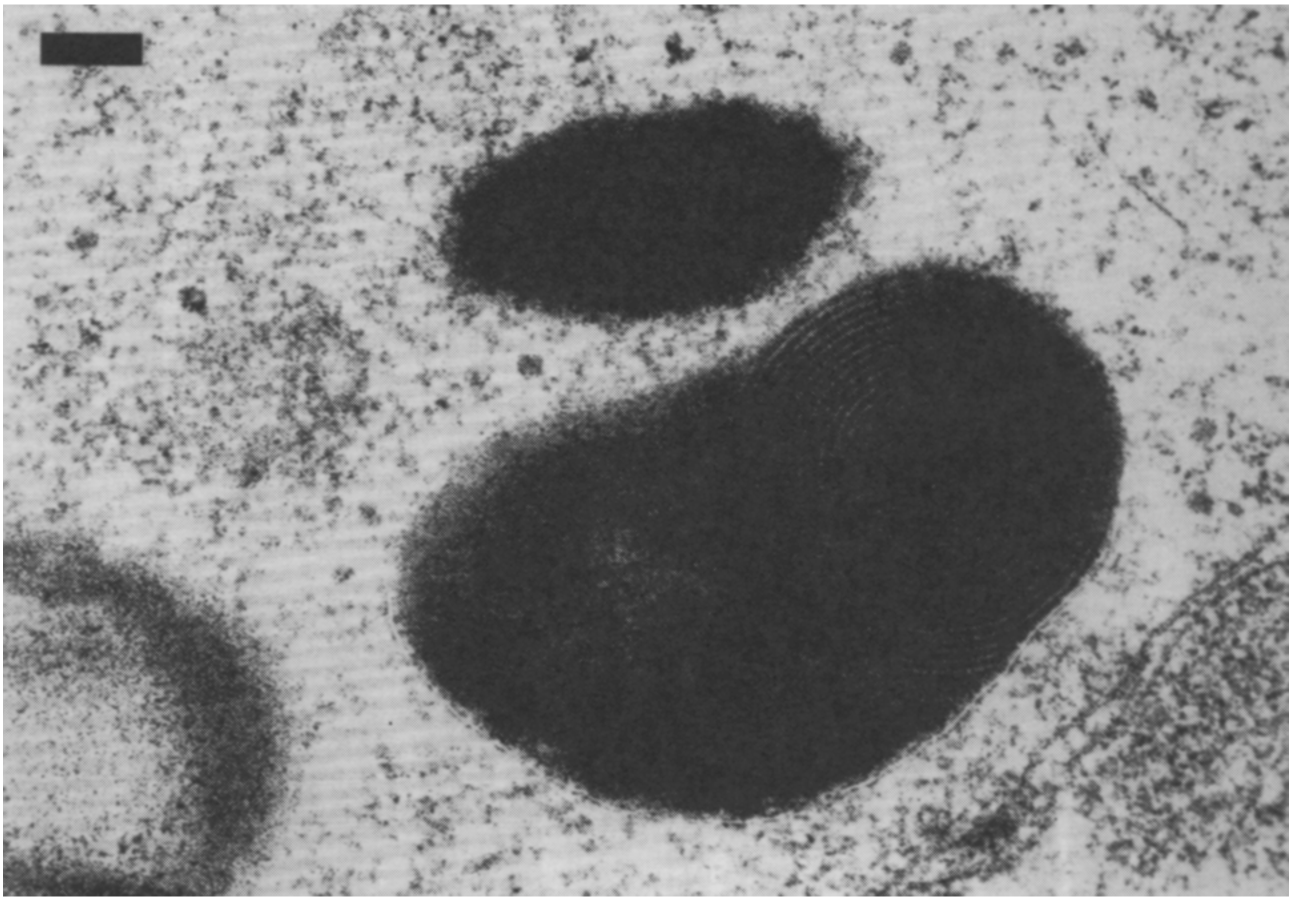

Figure 1. A transverse section of sheep spinal cord in the vicinity of an arteriole clearly depicting a lamellar body. Note the outer enveloping membrane into which the coil of phosholipid does not insert as occurs with lamellar bodies of highly active surfactant production in the lung by the alveolar Type II cell.[29] The bar represents 100nm.

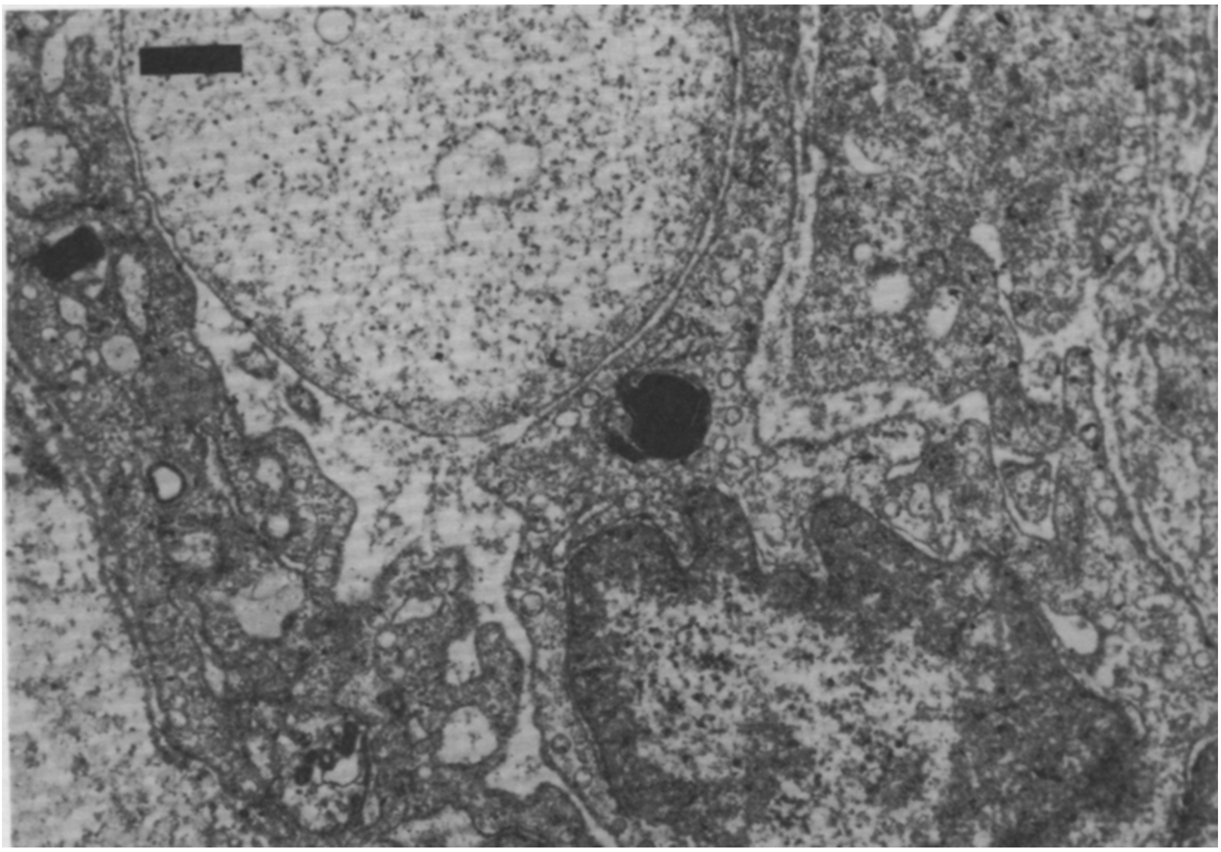

Figure 2. A transverse section of sheep spinal cord showing a lamellar body at lower magnification. The bar represents 500nm.

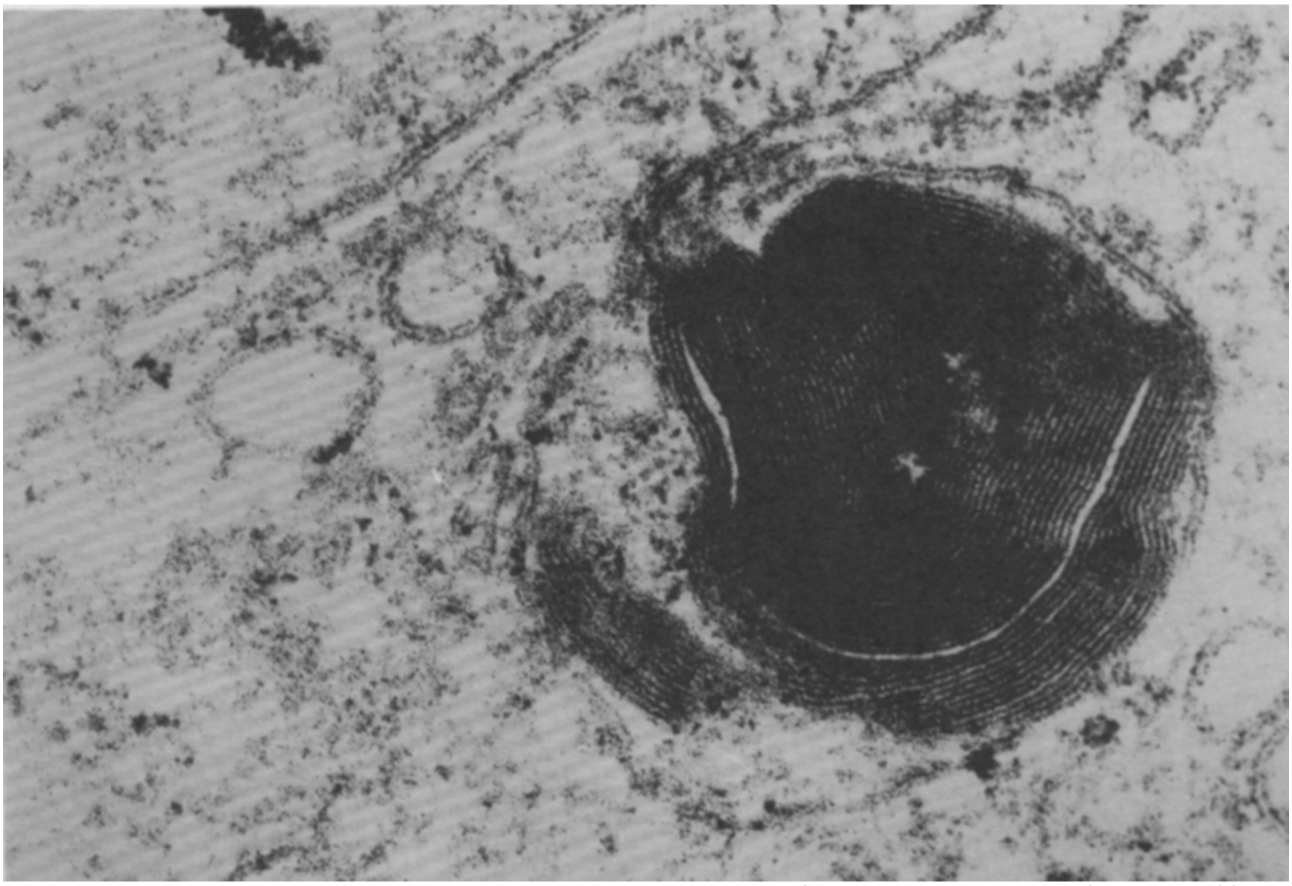

Figure 3. The same lamellar body shown in Figure 2 shown at higher magnification. Note the mutliple foci which, if found in the lung, would be termed a multilamellar body to which greater surface activity is attribute.[29]

Results

In two out of three animals lamellar bodies were clearly discernible in spinal tissue as shown in Figure 1. There were also a number with multiple foci known in the lung as "multi-lamellar bodies".[29] At lower magnification, these lamellar bodies can be seen in several tissue locations, including perikaryon, endothelial cells and peri-vascular glia (Figure 2), the lamellated structure and multiple foci being clearly discernible at higher magnification (Figure 3).

These lamellar bodies have a solid core which distinguishes them from vesicles such as lysosomes (Figure 4) seen in comparable numbers in perikaryon and as conglomerates of both (Figure 5) reported in perikaryal cytoplasm of rat cortex as "lipofusin granules".[30] At higher magnification the laminated nature of this complex is clearly discernible (Figure 6). Occasionally these hybrid granules can bee seen clustered quite close together (Figure 5).

Focus upon the vascular lining was frustrating, demonstrating a quite strongly osmiophilic vascular lining to endothelial cells (Figure 7). Upon higher magnification, however, this could not be resolved to reveal an oligolamellar phospholipid lining of the form recently discovered in sheep cerebral cortex.[21]

Discussion

Figures 1-3 leave no doubt that lamellar bodies are present in spinal tissue with a high proportion being multi-lamellar bodies. This is particularly interesting since, in the lung[29], these are even more surface active than regular LBs and should therefore be even more conducive to initiating bubbles upon decompression. The extreme surface activity of LBs and the unique form of this "packaging" can be appreciated from the ability to simulate "dry" surfactant as opposed to the "wet" form discussed by Bangham and co-workers.[31] The "dry" form has been credited with the ability to reduce the surface tension of water rapidly from 72 dynes/cm (mN/m) to "near zero"[32] or, even if such values are artifactually low[33], to less than 8 dynes/cm for a condensed monolayer[34].

Lysosomes would be expected to have the relatively low surface activity of other hollow-core vesicles such as liposomes of SAPL which typify "wet" surfactant.[31] It is a moot point whether conglomerates, seen in Figure 6, of lamellated phospholipid with multiple hollow and multiple solid cores, i.e. lipofusin granules, would be as surface active as LBs alone. Some indication might be afforded by the presence of very similar conglomerates in parietal cells from which their secretion to afford acid-protection by

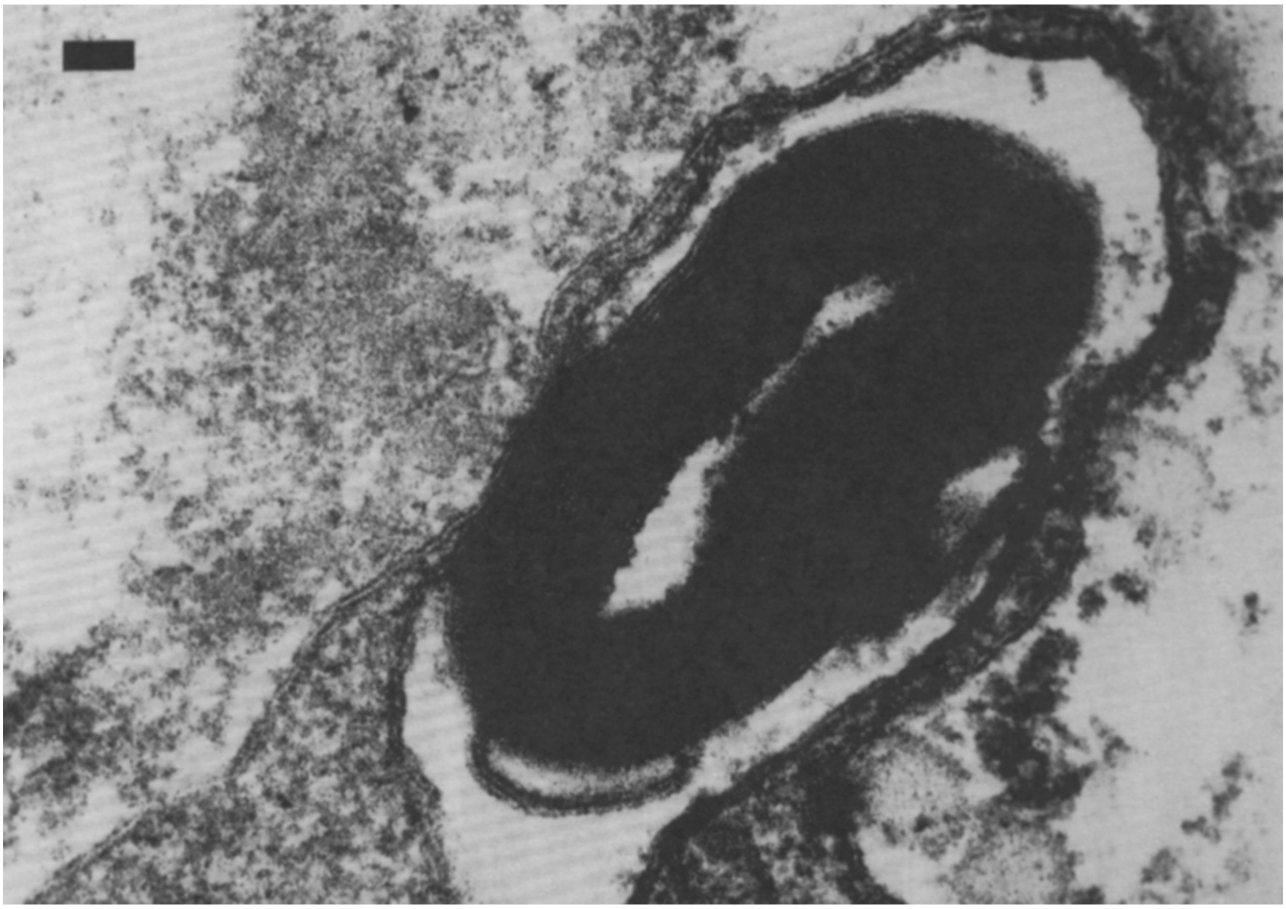

Figure 4. A transverse section of sheep spinal cord displaying a vesicle differing from lamellar bodies by posessing a hollow core. The bar represents 50nm.

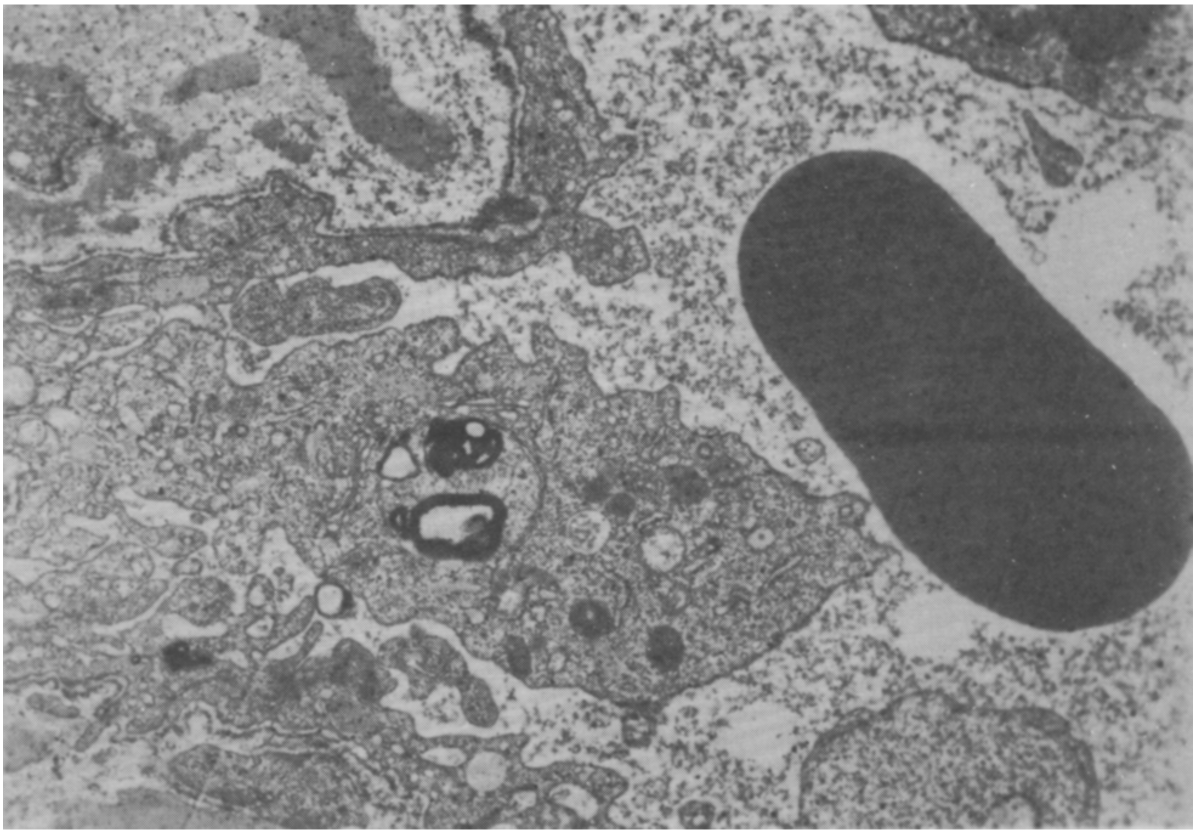

Figure 5. A transverse section of sheep spinal cord displaying an array of visicles clustered quite closely together in some areas and absent in others. Some of these vesicles resemble "lipofusin granules" previously reported in the brain.[30]

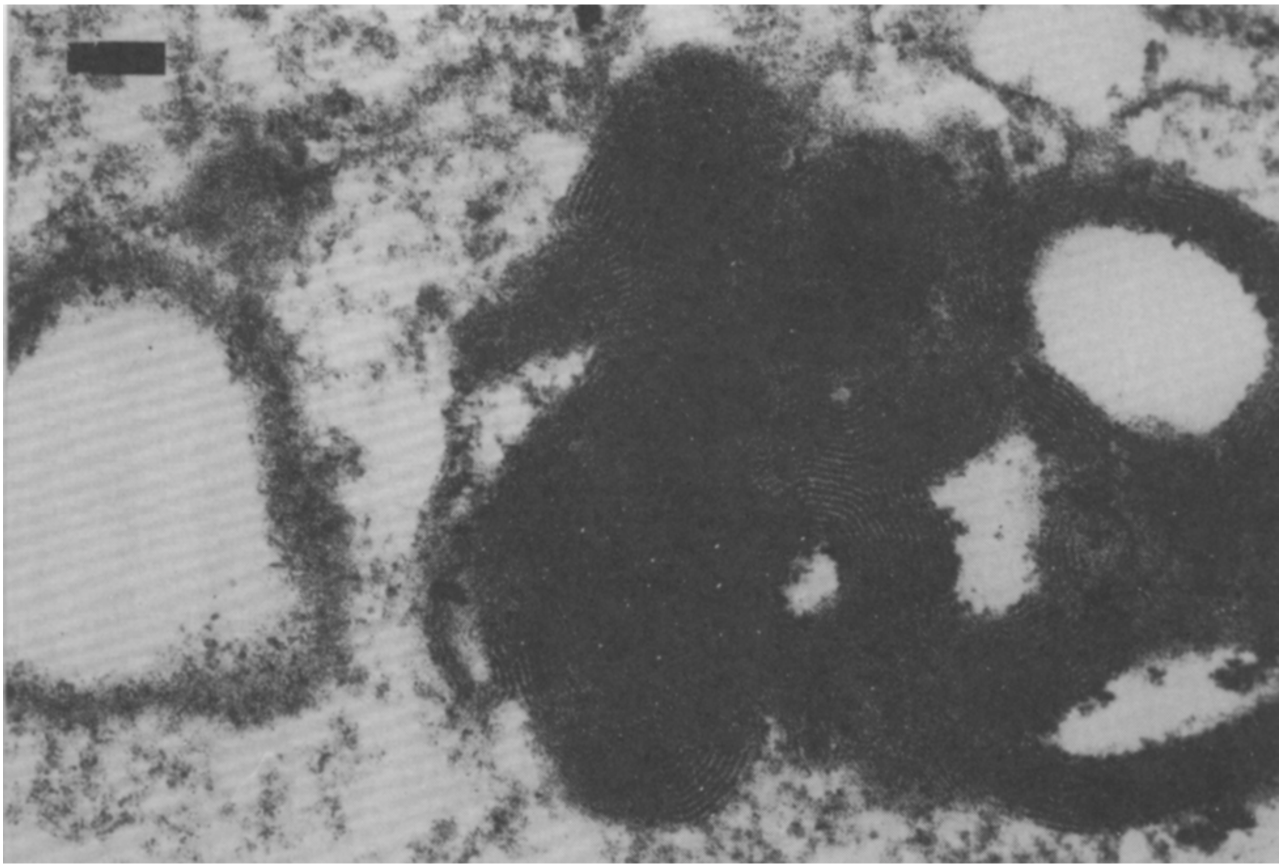

Figure 6. A "lipofusin granule" from Figure 5 shown at higher magnification when it can be seen to be a conglomerate of both solid- and hollow-core vesicles with phospholipid lamellations entwined one to another. The bar represents 50nm.

adsorption of SAPL to the apical surfaces of gastric epithelial cells has been attributed to their surface activity.[18] The same surface activity which renders SAPL or other surfactants so effective in reducing the surface tension of air-water interfaces is also effective at solid surfaces, functioning by adsorption to the surface.[14] The tendency for lipofusin granules to occur in clusters (Figure 5) or to be absent from a sequence of serial sections demonstrates a very variable incidence and distribution. It is also interesting that, in rats, these granules have been reported[30] to increase in number with age.

The propensity for bubbles to form in lamellated phospholipid is reflected in the fenestration of myelin seen upon autopsy of divers[2] and the observation in many decompressed animal tissues that bubbling occurred almost exclusively in the myelin sheaths.[35]

The similar variability in the incidence and distribution of lamellar bodies (Figures 2 and 5), and their potential for extreme surface activity, indicates that this could be a major factor in determining the distribution of bubbles for a given degree of tissue supersaturation by gas and could have a major influence in determining individual susceptibility. Other factors such as the white:grey matter ratio and random features of the microcirculation, such as intermittent perfusion[36], must also be important in determining the local level of supersaturation and, hence, separation of gas from solution. However, these factors would not appear as variable as the incidence and distribution of LBs and their conglomerates.

If LBs are a major factor in determining individual susceptibility, it could explain one very puzzling observation. This is the propensity for neurological DCS to occur upon surface decompression as discovered using goats in carefully titrated decompressions[37] and subsequently confirmed by much field experience. It was found that any "upward excursion" at the start of decompression predicted to induce supersaturation for however short a period, e.g. 1 minute[37], caused the presenting symptoms upon titration of the decompression to be neurological rather peripheral, i.e. Type II rather than Type I DCS. Some mechanism must be "triggered" during an upward excursion or surface interval and it is tempting to suggest that the LBs in the CNS are "activated" into bubble formation.

The tantalising question arising from this electron microscopy is what normal physiological function could be attributed to lamellar bodies in spinal tissue. A major search of the literature has revealed LBs in conventional electron microscope studies of many tissues, including spinal tis-

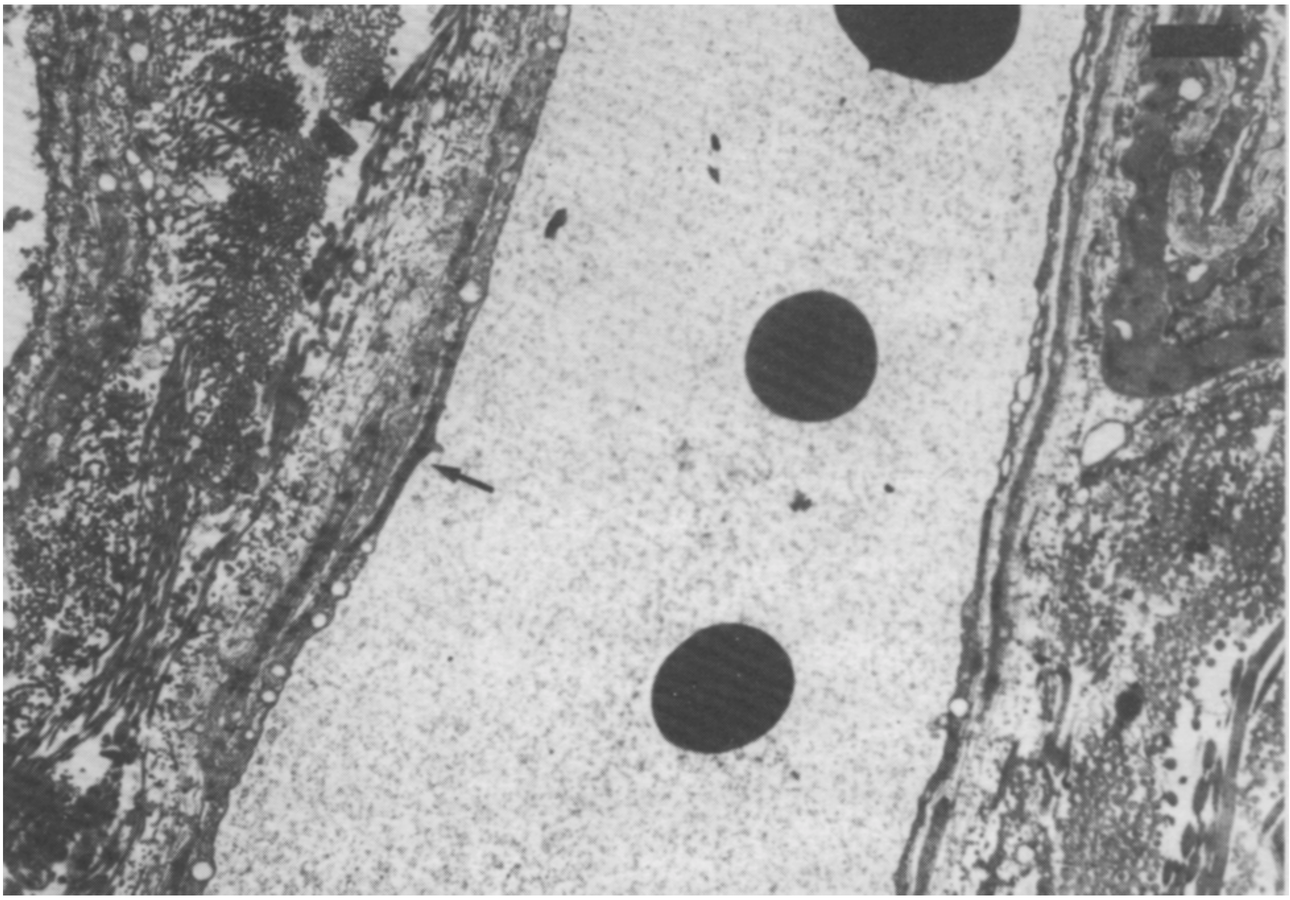

Figure 7. A longitudinal section of a venule in sheep spinal cord. Note the osmiophilic nature of the endothelium indicated by the arrow. The bar represents 2 µm.

sue[30], but they are usually ignored or dismissed by some morphologists as the membranous remains of dead cells. This explanation is difficult to accept even for lipofusin granules within non-phagocytic cells, but the remarkable similarity to LBs in the alveolar Type II cell indicates that they have been produced for a purpose. One possible function reflecting their propensity for peri-vascular sites is to provide or enhance an endothelial lining, a high incidence of LBs having been reported in aortic endothelial cells.[38] Such a lining has been implicated by factors influencing blood pressure[33] and by electron microscopy of cerebral cortex.[21] It was therefore tantalising to demonstrated an osmiophilic luminal lining to the endothelium of spinal tissue (Figure 7) and yet not to the able to resolve it with higher magnification into the oligolamellar structure seen in cerebral cortex. On the other hand this difference might explain why spinal tissue is more susceptible to circulating bubbles known to open the blood-brain barrier[22,23], despite receiving only 2% of those entering the CNS on the basis of blood flow distribution.[5]

In conclusion, it was surprising to find lamellar bodies in spinal tissue, but their widely differing incidence and distribution might prove a useful lead in explaining the variation in individual susceptibility to spinal DCS. If nothing more, this study provides morphological evidence of surfactant in a highly surface-active state for the type of bubble, and nucleus - stabilization long emphasized by Yount.[11,12]

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COMPUTER RECREATION

David Brookman

All diving computers continually sample pressure and time, either using an algorithm, or a look-up table, to determine approximate nitrogen saturation from a theoretical model of the human body. Dissolved nitrogen is estimated in a series of tissue compartments ranging from one to many (there is an infinite continuum in which nitrogen may dissolve) which for mathematical simplicity are usually limited to about 6 to 12.[1,2] The concept of tissue compartments and the mathematical model of nitrogen uptake and elimination were derived by J.S.Haldane.[3] Some dive computers provides a record of the diver's depth-time profile and this can later be used to review the dive profile, and for comparatively accurate estimations of air consumption. These results in turn allow detailed dive planning.

Computer models of breathing gas usage and nitrogen gradients are a useful means of presenting graphically what may happen during a dive. They are idealised and hence cannot be used as an accurate representation of physiological reality.

This paper grew from electronic doodling using a spreadsheet (Microsoft Works) with an accompanying charting program. It is easy to calculate variations associated with nitrogen uptake and air consumption. I have used an IBM compatible with only 1 megabyte of random access memory, so my models have been limited to 5 tissue compartments with half-times of 2.5, 5, 10, 20 and 40 minutes, but these are the ones relevant to sports dives of less than 60 minutes duration and not suitable for repetitive dive calculations.

Using a computer to estimate air consumption

Obviously air consumption is dependent on the amount of physical work the diver does and his or her breathing rate. The latter is dependant on the pH of the CSF (which depends on blood CO_2 levels), the partial pressure of oxygen in the arterial blood (both are affected by exercise) and the psychological state. Lippmann[4] gives a method of calculating air consumption in his book that is limited in accuracy by the approximation to a trapezoidal dive profile.

Using a computer that replays a depth-time profile will give 3 minute samples of depth that allows the derivation of a weighted average of the depth (or an estimate of the integral of the depth/time curve). Table 1 provides such a profile.

In this table the respiratory minute volume (RMV) has been calculated (it is directly reproduced from the spreadsheet). The method of calculation is:

TABLE 1

Dive time		44 minutes
Fill pressure	280 bar	276.41 atm
End of dive pressure	70 bar	69.10 atm
Air cylinder water capacity		10 l

Depth (MSW)	Time (minutes)(atm)	Pressure
15.0	3	2.58
23.4	6	3.32
31.2	9	4.10
32.7	12	4.24
32.4	15	4.21
30.9	18	4.07
22.5	21	3.23
16.2	24	2.61
14.7	27	2.46
10.5	30	2.04
8.4	33	1.83
7.8	36	1.77
9.9	39	1.98
7.2	42	1.71
0	45	0.00
0	48	0.00
0	51	0.00
0	54	0.00
0	57	0.00
0	60	0.00

Sum of pressure * time	120.48 atm.min
Average pressure	2.74 atm
RMV	17.21 L/min at 1 atm

TABLE 2

Dive time		61 minutes
Fill pressure	210 bar	207.31 atm
End of dive pressure	50 bar	49.36 atm
Air cylinder water capacity		11.4 l

Depth (MSW)	Time (Min)	Pressure (atm)
11.4	3	2.13
11.1	6	2.10
8.4	9	1.83
5.7	12	1.57
5.1	15	1.51
7.5	18	1.74
9.6	21	1.95
9.3	24	1.92
9.3	27	1.92
8.7	30	1.86
7.5	33	1.74
6.9	36	1.68
11.1	39	2.10
10.8	42	2.07
9.6	45	1.95
11.4	48	2.13
10.8	51	2.07
9.3	54	1.92
8.1	57	1.80
4.8	60	1.48

Sum pressure * time	112.50 atm.min
Average pressure	1.84 atm
RMV=	16.01 L/min at 1 atm

For each depth:

Pressure = (depth/10.8)+1 (atm)

For the whole dive (where T = duration of dive)

Mean pressure = (1/T) *sum(pressures *3) (atm)
(the 3 is the three minute sampling intervals)

and finally where Pe = tank pressure at end (bar)

Pf = tank filling pressure (bar)
C= water capacity of tank (litres)

RMV = (Pf-Pe) * C/ (T * P) litres/min (at 1 atm)

Greater accuracy could be obtained if the times of variations of the diver's physical activity and the tank pressure at the time are recorded. RMV's can then be calculated for each phase of the dive. It is doubtful that such accuracy is valid or desirable as it represents a sampling variation of the experimental result, and intrudes into the enjoyment of diving.

Table 2 demonstrates the same calculation for a shallower but longer dive.

Estimating nitrogen gradients

Haldane proposed a limit to the rate of ascent of a maximum ratio of nitrogen partial pressure to ambient pressure of 1.58. As nitrogen is the dominant inert gas involved (CO_2 and O_2 being chemically interactive are not usually included in the determination of partial pressure) this equates to a ratio of 2:1 of nitrogen partial pressure to ambient pressure.

Using the Haldane model with tissue compartments with half times of 2.5, 5, 10, 20 and 40 minutes it is possible to graph the changing nitrogen partial pressures (which equate to tissue saturation) for each dive. Figure 1 represents the dive of Table 1 showing the nitrogen partial pressures in each compartment, and Figure 2 shows the dive of Table 2.

The U.S. Navy tables have been derived using the Haldane model. Data from experimental dives suggest that the Haldane model is too restrictive where fast tissues are involved, and may not be adequate where slow tissues are considered. Slow tissues affect the repetitive dive estimations of residual nitrogen which are not the subject of this

Fig 1
Haldane Model – Dive 120

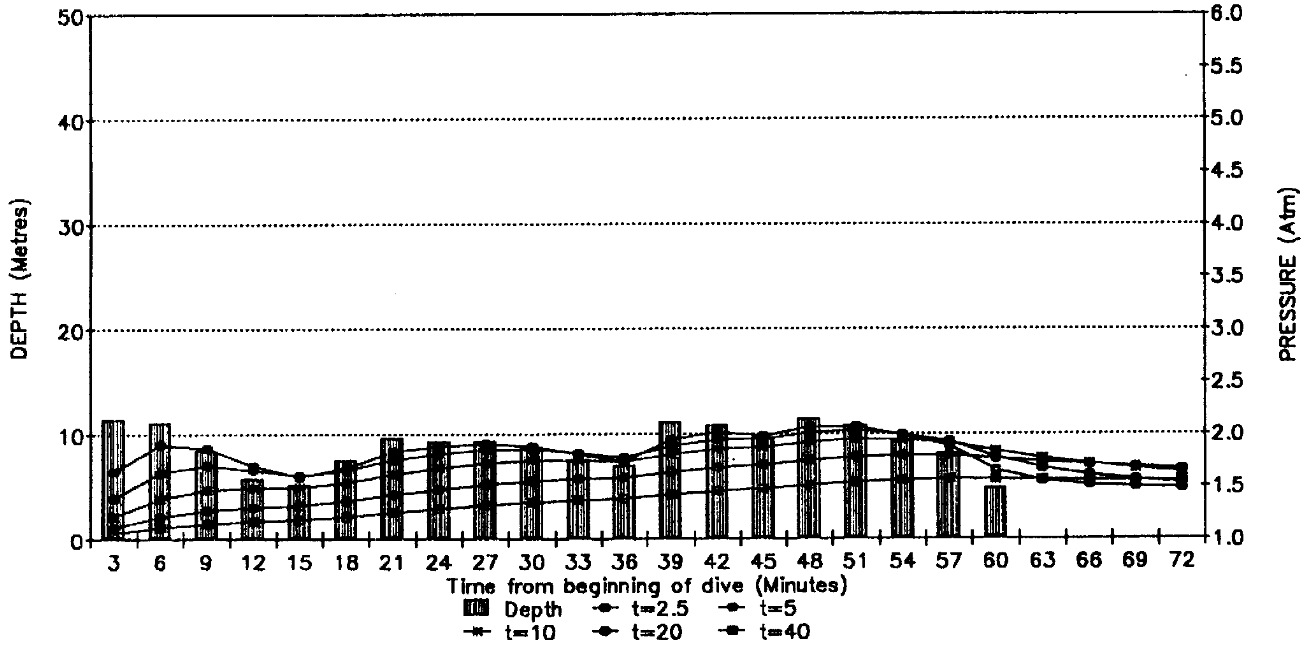
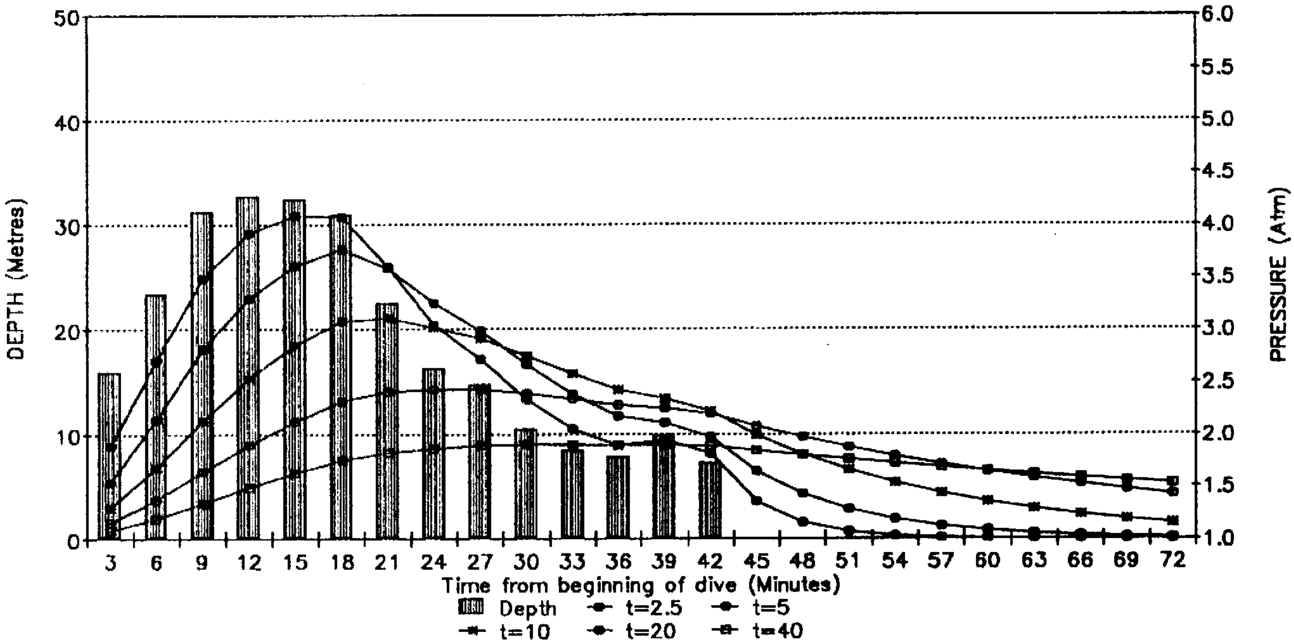


Fig 2
Haldane Model – Dive 121



paper. The nitrogen gradient can be used to demonstrate the desirability of slow ascents from deep dives and the effect of staging and decompression stops. Readers who are interested can readily analyse individual dives (if they are wearing the appropriate dive computer) as a teaching exercise. It may also be useful to those divers who are not fit, lean, males aged between 20 and 30 years of age who wish to modify their dive profiles to minimise their nitrogen gradients.

Table 3 shows an nitrogen gradient calculation for a comparatively deep dive.

TABLE 3

Depth (MSW)	Time (minutes)	Relative Ambient (atm)	Nitrogen Pressure Gradient	Nitrogen Gradient Ratio
35.7	3	3.54	1.54	3.54
37.2	6	3.69	0.74	0.64
36.6	9	3.63	0.29	0.85
36	12	3.57	0.10	0.95
37.2	15	3.69	0.1	0.95
36.9	18	3.66	0.03	0.99
21.6	21	2.14	-0.79	-1.47
12	24	1.19	-1.15	-1.80
8.4	27	0.83	-1.16	-1.82
4.8	30	0.48	-1.23	-2.03
4	33	0.40	-1.07	-1.94
4	36	0.40	-0.88	-1.76
0	39	0	-1.15	-2.28
0	42	0	-1.04	-2.15
0	45	0	-0.94	-2.04
0	48	0	-0.84	-1.94
0	54	0	-0.69	-1.76
0	57	0	-0.65	-1.69
0	60	0	-0.62	-1.65
0	63	0	-0.59	-1.62
0	66	0	-0.56	-1.59

These calculations can be reproduced graphically (the dark bars represent the gradient ratio, the light the actual estimated pressure). Figure 3 shows the dive of Table 3, and Figure 4 shows another better executed dive with a slower ascent time and longer staging but of similar depth and more suited to those not fulfilling the physical criteria of the U.S. Navy's divers.

Dive planning

Data derived from the above dive analysis can be used to plan new dives in greater detail. It is a moot point whether this is desirable as it may encourage some to push their air supply to its limits and thereby create "out of air" crises and hence subject themselves to the risk of decompression illness. Therefore I would not envisage this as being useful for any but the most experienced divers who are planning exceptional dives and for those involved in teaching. The rule of thumb recommended by most of the training agencies of one third out, one third back, one third reserve should be maintained. Where this planning function may be useful is pre-dive estimation of the nitrogen gradient (particularly for those at greater risk of DCS), and for demonstrating to students the change in the tank pressures that can be expected throughout the dive.

Table 4 gives a projected dive which would exceed the expected safety limits and hence should not be con-

Fig 3

Nitrogen gradient (Haldane Model) — Di

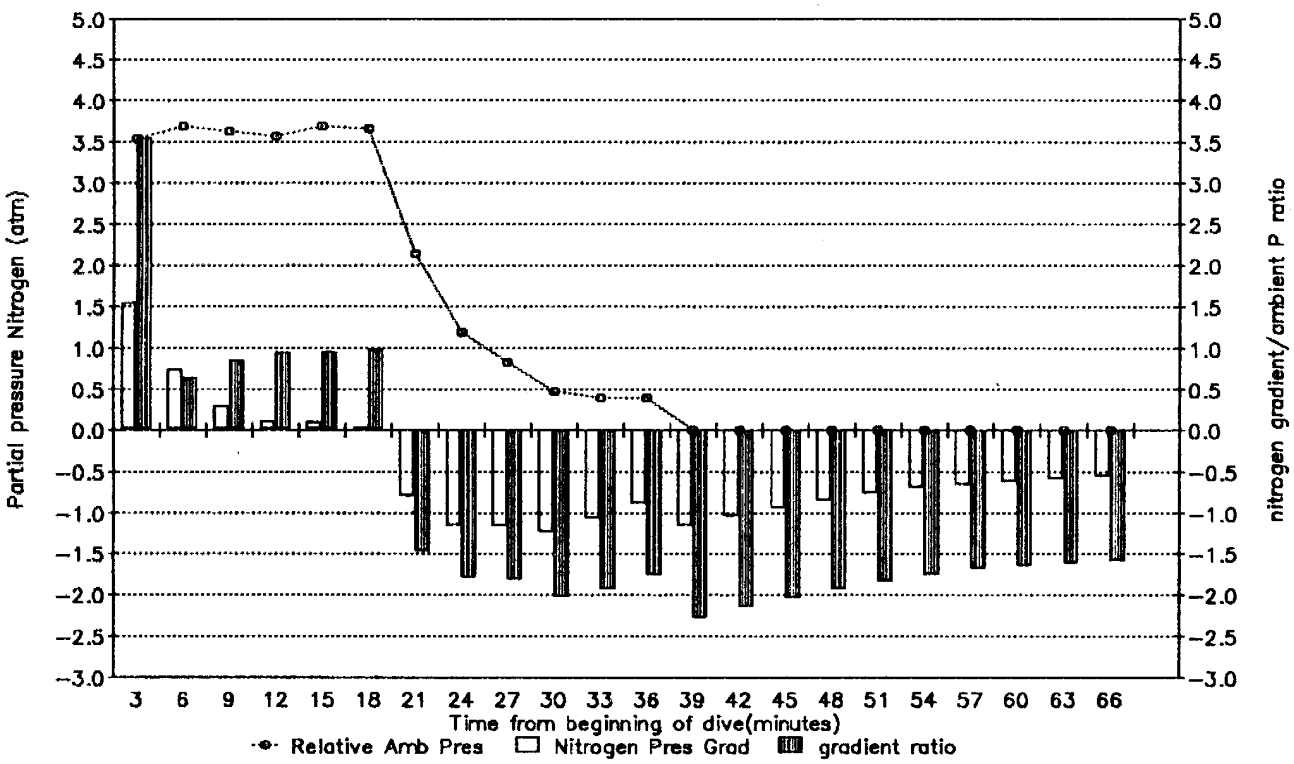


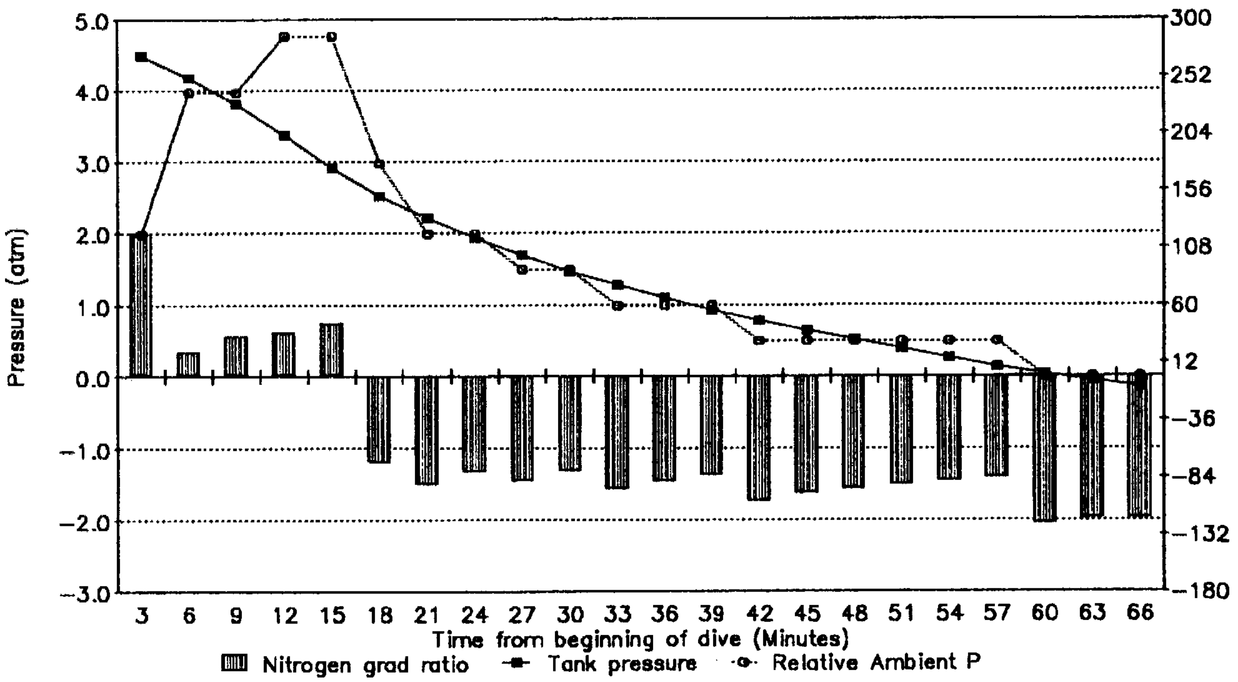
TABLE 4

Depth (MSW)	Time (minutes)	Relative Ambient Pressure (atm)	Nitrogen Pressure Gradient (atm)	Nitrogen Pressure Ratio (atm)	Tank Pressure (bar)
20	3	1.98	1.31	1.98	269
40	6	3.97	2.17	0.34	251
40	9	3.97	1.43	0.56	228
48	12	4.76	1.47	0.61	202
48	15	4.76	0.97	0.74	174
30	18	2.98	-0.54	-1.21	151
20	21	1.98	-1.01	-1.51	132
20	24	1.98	-0.67	-1.34	116
15	27	1.49	-0.80	-1.47	101
15	30	1.49	-0.65	-1.38	88
10	33	0.99	-0.93	-1.58	77
10	36	0.99	-0.76	-1.47	66
10	39	0.99	-0.62	-1.38	56
5	42	0.50	-0.94	-1.74	47
5	45	0.50	-0.85	-1.63	39
5	48	0.50	-0.77	-1.57	31
5	51	0.50	-0.69	-1.51	23
5	54	0.50	-0.62	-1.49	16
5	57	0.50	0.56	-1.42	8
0	60	0	-0.98	-2.06	2
0	63	0	-0.98	-1.98	2
0	66	0	-0.98	-1.98	2

Cylinder fill pressure = 280 Bar Cylinder water capacity = 101 litres Respiratory minute volume = 16.8 L/min

Fig 4

Dive Planner



ducted.

The dive is demonstrated graphically in Figure 4. The failure in this dive is the inevitable out-of-air risk though the decompression stops are quite conservative. A diver with this profile would need to resort to extra air (a spare tank hanging at the 5 m decompression stop) even assuming that the Respiratory Minute Volume did not change from the diver's average (i.e. exceptional physical activity was not required and no anxiety was aroused) and such an assumption cannot be the basis for a safe deep dive.

Obviously greater sophistication of the computer model could be achieved if RMV's for differing levels of activity were included. Such a step is not desirable given the use to which this model should be put.

There have been articles criticizing the use of dive computers because they lack the inherent safety margin imposed by the maximum square profile resulting from the use of the tables. It is postulated this prompts divers to push their dive to the limits of the computer. Others have lauded computers as they reduce the risk of miscalculation by the narcosed diver! Both are probably correct. Dive computers are merely tools. Their use is another art that must be acquired by divers to minimise their risk of decompression illness. Computers that record the dive profile allow the analysis of divers' profiles and can show if they are misusing the computer. They also provide a useful record should the diver be unfortunate enough to suffer a decompression illness. Analysis of the dive profile could allow some judgement to be made of where the dive went wrong, rather than relying upon the diver's imperfect memory.

References

1 Edmonds C, Lowry C and Pennefather J. *Diving and subaquatic medicine.* 2nd edition. Sydney: Diving Medical Centre, 1983; chapter 7

2 Lippmann J. *Deeper into diving.* Melbourne: JL Publications, 1990; chapter 12 et seq

3 Lippmann J. *Deeper into diving.* Melbourne: JL Publications, 1990; 177-181

4 Lippmann J. *Deeper into diving.* Melbourne: JL Publications, 1990; chapter 29

5 Lippmann J. *Deeper into diving.* Melbourne: JL Publications, 1990; 177-184

6 Edmonds C, Lowry C and Pennefather J. *Diving and subaquatic medicine.* 2nd edition. Sydney: Diving Medical Centre, 1983; 145-146

Dr David Brookman's address is 57 Kensington Road, Bolwarra, New South Wales 2320, Australia.

SPUMS NOTICES

SPUMS ANNUAL SCIENTIFIC MEETING 1993

This will be held at the Pan-Pacific Hotel in Palau in May or early June 1993. The exact date is still to be fixed.

The guest speaker will be Professor David Elliott, co-author with Dr Peter Bennett of The Physiology and Medicine of Diving. He is an excellent teacher and an entertaining speaker.

As there has been much interest in this venue from members and associates the Committee considers that those who usually leave their decision to the last minute (and there are many) are likely to miss out because the hotel will have sold the rooms not booked by SPUMS to others.

To make certain of being able to accommodate all those who wish to attend it has been decided that there will be a cut off date, the **14th of December 1992**, when hotel bookings will be made, and rooms guaranteed, for all those who have applied to Allways Travel enclosing a deposit of $Aust 600 per person.

Every attempt will be made to provide accommodation for those who decide, after the cut off date, to attend but they may be disappointed. The message is book early and be certain of attending.

MINUTES OF EXECUTIVE COMMITTEE TELECONFERENCE SUNDAY 16TH FEBRUARY 1992 AT 10:00 EST

Apology

Dr Tony Slark

Present

Drs Des Gorman (President), Darrell Wallner (Secretary), Grahame Barry (Treasurer), John Knight (Editor), David Davies (Education Officer), Chris Acott, S Paton and John Williamson.

1 Minutes of previous meeting

The Minutes were read and accepted as a true record. Proposed by Dr Knight, seconded by Dr Barry.

2 Business arising from the Minutes

2.1 A.G.M PORT DOUGLAS

Dr Williamson reported that the Scientific Program is nearly complete. Some short Hyperbaric Medicine papers are still being prepared.

Chairpersons for the Quicksilver sessions will be appointed as available for each trip. There was some concern that registration numbers are down. Advertisements are to be placed in the Medical Journal of Australia Bulletin, The Dive Log and Doctors' Weekly. Geoff Skinner's trip to DEMA has resulted in about 100 new SPUMS member enquiries. For overseas visitors the pre- and post- conference dive package may be too limited and Dr Paton will discuss with Allways the feasibility of distributing a list of alternative tours to overseas members with Allways acting as an agent. However, this would necessitate air mailing to all the American members.

2.2 PALAU MEETING

Consideration to be given to an April-May date for the A.G.M.

2.3 P.N.G. MEETING

No progress.

2.4 ANZHMG

Dr Williamson reported that the meeting on 2nd December was successful and the group is very enthusiastic. The second meeting will at Port Douglas. There will be a need for 2 further teleconferences which SPUMS is happy to underwrite.

Surgeon Commander Tim Dillon, at Canberra, will be the Secretary of the group.

Darwin's hyperbaric unit will be maintained. Christchurch's unit is having difficulties. The Hyperbaric Medicine field is rapidly expanding with advice being sought by Palau, Kiribas and Fiji on retrieval systems for their chambers.

The DES number is being used frequently. There is some pressure from other organisations to use it for other emergencies other than diving. This is not being encouraged.

At the moment there are two retrieval services in North Queensland - The North Queensland Emergency Response Group and the Royal Flying Doctor Service.

2.5 DIVE COMPUTERS

Dr Acott will commence his paper shortly.

2.6 OXYGEN CYLINDERS ON DIVE BOATS

Dr Paton will follow this up with Allways Travel.

2.7 DIVING AND DIABETES

Dr David Davies' paper will be published in SPUMS Journal (1992; 22 (1): 31-32) as a SPUMS policy on this subject.

3 Diving doctors list

3.1 RANSUM

After some difficulty Surgeon Commander Strack will provide a list, probably incomplete.

3.2 RAH DIVING MEDICAL COURSE

The Adelaide List has been received. It was agreed that SPUMS application forms be given to all people completing the Adelaide and RANSUM courses.

3.3 NEW ZEALAND LIST

New Zealand list not yet received.

3.4 All non-members who have done the courses will be contacted asking them to join and if they desire, be placed on our published list of Diving Doctors.

3.5 ANNUAL SUBSCRIPTION NOTICE

This will incorporate a questionnaire asking for details of diving Medicine Training and the addresses for Diving Examinations. This will enable us to keep our list easily updated.

3.6 DIVE INSTRUCTOR GROUPS

The Secretary will contact BSAC, NAUI, AUF and PADI asking them for their dive shop locations so we can identify areas where there is a lack of trained Diving Doctors. When we receive this information, Drs Gorman and Williamson will be able to correlate these areas with our list of diving doctors, probably with the help of medical students.

4 Standards Australia

The Recreational Standard AS 4005.1-1992 will be available soon. The medical examination form is basically our recommended form to the Committee CS/83. The SPUMS Diving Medical will be printed as a booklet and distributed with the March Journal.

5 AMA letters

The full correspondence will be available for the next committee meeting.

6 Treasurer's report

6.1 There will be a sub-committee (Secretary, Treasurer and Editor) meeting in Canberra in March to discuss streamlining various secretarial and accounting arrangements.

6.2 Credit Card Facilities. At the moment all new members pay by cheque. The opening of this facility is to be done by the Treasurer (Dr Barry).

7 Correspondence

7.1 The Editor's letter to Dr P Wilmshurst of the BS-AC regarding his attack on Dr Adkisson was tabled and approved.
7.2 Letter asking for information on a the Spirometer. Dr Gorman will deal with this.

8 Other business

8.1 Dr Williamson informed the meeting that he is on the Federal Committee of the Australian Resuscitation Council which is preparing a 1st Aid for Divers policy document for publication.
8.2 Also that an Australian Tropical Medicine Institute has been opened in Townsville.

9 Next Committee Meeting
Sunday, 31st May 1992, at 1800 at the A.S.M.

SPUMS MEETING, TATHRA MARCH 14TH AND 15TH.

Convener Dr Geoffrey Long

Twenty six registrants, made up of SPUMS members and other doctors interested in diving medicine, attended the SPUMS meeting at Tathra. Most were accommodated at the same hotel as the conference and so could meet on the Friday evening and get to know each other.

On Saturday afternoon there was an interesting and varied selection of speakers and topics. Dr Darrell Wallner, Secretary of SPUMS, spoke on Sting Ray injuries. His son, Bruce, related some marine environmental studies undertaken in Jervis Bay. Dr Rob Heard gave a neurology update and Dr Simon Bass discussed Asthma and Diving. Dr Michael Bennett spoke about aero-retrieval of diving accidents and Paul Cozens, the dive leader, delivered a paper entitled "Open Water 1 Training and its Shortcomings".

The keynote speaker for the afternoon was Dr Carl Edmonds who, with the help of the questionnaire reproduced with this report, told us about the limitations of our equipment at depths greater than 30 m. Most of the answers can be found in the SPUMS Journal Vol 22 No 1. The audience of about 50 people, which included local diving identities, was attentive and appreciative. In the evening a dinner was enjoyed by nearly sixty doctors, divers, wives and husbands.

Questionnaire

Equipment limitations in excess of 30 m

1 What weight should a diver carry (on average) ? Give a specific figure. No waffle.

2 What is the "I want to buddy breathe signal" ?

3 What is the buddy's usual response to a buddy breathing request at 39 m (130 ft) ? Why ?

4 Why should buddy breathing have failed ?

5 At 39 m (130 ft) and 35 bar (over 500 psi) how long does it take to add 10 litres of air to a BC, if you are breathing for the regulator at about 60 l/min (moderate exertion) ?

6 Under those conditions, how many minutes would you be able to stay down there before you felt resistance to breathing ?

7 How many more minutes before you were totally out of air ?

8 How could the absence of one fin contribute to death?

9 At 39 m (130 ft) and 35 bar (over 500 psi) how long does it take to add 10 litres of air to a BC ?

10 In diving fatalities how often does the victim ditch his weights ?

11 What usually innocuous physiological abnormality may predispose to cerebral decompression illness in divers who dived within the tables ?

12 How many previous no-decompression dives could the dive master have done that day ? He followed his dive computer, went to 30 m each time and had 8 minutes bottom time (10 minutes total dive time) on each dive.

LETTERS TO THE EDITOR.

THE END OF NO-DECOMPRESSION DIVING

Telita Cruises
PO. Box 303, Alotau
Papua New Guinea
April 20th 1992

The Editor,

I was of course delighted to see my letter and article published in the January-March issue. But, alas, the gremlins struck. The title of my article was "The end of NO-decompression diving". You omitted the NO from both the piece and the index. I would be grateful for a correction since the title as printed makes no sense. and I hate to give fuel to those who think I am crazy.

Bob Halstead

The Journal apologises for the mistake made in reprinting Mr Halstead's article. A corredtion will be made to the index which is in preparation.

ASTHMA AND DIVING

Diving Medicine and Assessment Centre
4 Dodson Ave
Milford, Auckland 10
NEW ZEALAND
11 March 1992

The Editor,

The debate as to whether asthmatics should scuba dive has, with some justification, persisted in diving medical publications. The known, theoretical risk of air embolus, in addition to the increased risk of provoking an asthma attack, continue to give diving physicians difficulty explaining to, and declining, enthusiastic dive candidates.

The SPUMS Journal published the New Zealand diving-related fatalities 1983-84[1], compiled by Douglas Walker, which had been previously presented to a pre-SPUMS meeting at Tutukaka by Surgeon Commander Peter Robinson. On reviewing the 20 case studies of diving deaths, 10 had medical contra-indications to scuba diving and 5 (25%) were known asthmatics. Even accepting these figures of 10 scuba diving deaths per year, (other observers recorded 12 diving deaths per year over this period of time), there were far too many diving deaths in patients who had medical contra-indications. These deaths were a major factor stimulating the formation of the New Zealand Chapter of SPUMS, the holding of conferences on diving medicine in New Zealand, and the publicity of risks of diving, with emphasis on the medical contra-indications.

Returning to the question of asthma, a 25% incidence in diving deaths is much higher than one would expect from a cross-section of the New Zealand population, in which respiratory physicians estimate under 5% have significant asthma, and 15% have reactive airways.

There appears to be much conflicting literature on asthma in diving medical journals. The numbers of diving deaths recorded here of 10 per year in a population of 3 million, is very significant. Subsequent figures have demonstrated a drop in the number deaths of persons with medical contra-indications to diving.

Allan F.N.Sutherland

Reference

1 Walker DG. Provisional report on New Zealand diving-related fatalities 1983-1984. *SPUMS J* 1986; 16 (2): 43-54

RADIOLOGY AND DIVING

Health & Safety Executive
Field Operations Division
Fraser Place, Aberdeen AB9 1UB
United Kingdom
12 March 1992

The Editor,

As part of the on-going revision and updating of its guidance on statutory medical examinations and with the over-riding wish to minimise radiation exposure, Health & Safety (HSE) has reconsidered the need for long bone radiographs of commercial divers.

The primary reasons for radiography of the hips, knees and shoulders in divers have been the detection of existing bone lesions at the commencement of diving and the early detection of osteonecrotic lesions during a diver's career. It has been acknowledged that such surveillance is particularly appropriate in certain categories of diving.

Various factors have influenced us in the decision to change the guidance. These include:

1 As mentioned above a wish to reduce the overall radiation exposure of divers.
2 A wish to shift the emphasis of the medical examination from screening towards surveillance in relation

to occupational risk and hence to produce information to aid the diver in reaching decisions about his health and work.

3 A belief that there should be a balance between the risks of radiation and the benefits to be gained by the diver and hence that radiography should be the subject of counselling and informed consent.

4 Our understanding that the incidence of disabling osteonecrotic lesions is very low. Lesions are particularly rare in the air diving range

5 Whilst the detection of a lesion has no influence on the likelihood of other future lesions the continuance of diving of the same kind may lead to other lesions. The disabling effect of a lesion (if juxta-articular) will naturally be increased by the development of disease in other joints.

6 That the removal from diving work of a diver with established osteo-necrotic disease does not arrest the progress of that disease and further that the condition is not amenable to currently available treatment.

7 In diving, lesions of the shoulder and hip greatly exceed those in the knees.

8 Finally, that the finding of a bony lesion at the pre-employment stage would not necessarily, of itself, preclude diving.

We therefore recommend that the practice of **routine** pre-employment long bone radiography should cease. Similarly **routine** radiography prior to Part 1, Part III or Part IV training should also cease. However, radiography of the hips and shoulders and knees should be carried out before the commencement of Part II training and of the hips and shoulders at intervals thereafter whilst the diver is still engaged in mixed gas or saturation diving.

Factors in the decision would be those currently advised in MA1 Para 40 subject to the clinical judgement of the examining doctor in the light of the diver's history and the results of clinical examination. Radiography may be advised on clinical grounds in situations other than those described.

If radiography is not judged necessary on other grounds, it should be repeated at intervals of 5 years during a diver's career.

The decision to radiograph the long bones should be the subject of agreement between the diver and the examining doctor - that is to say the diver should give his or her informed consent.

Examining doctors would retain the right not to issue a certificate of fitness if they felt that radiography was of crucial importance to their decision on fitness in any particular case and the diver would not agree.

Dr E M Botheroyd
Senior Employment Medical Adviser
Health & Safety Executive

HIGH TECH DIVING

Fund Dive Centre
255 Stanmore Road
Stanmore, New South Wales 2048
28 April 1992

The Editor,

I read with interest the editorial "High Tech Diving" by Dr Des Gorman in the January-March 1992 (Vol 22 No 1) issue of the SPUMS Journal. I would like to point out that two statements made by Dr Gorman are inaccurate and likely to lead to misinterpretation of the High Tech Divers' intentions, thereby damaging their credibility.

Dr Gorman's statement that this group "plans to use scuba apparatus and oxygen-helium, perhaps trimix, gas mixtures to dive beyond 50 msw, and according to some press releases, as deep as 200 msw" is incorrect. The above-mentioned High Tech Divers have never expressed intentions to dive to 200 msw, nor have they planned to do so on open circuit scuba equipment.

Dr Hamilton's association with High Tech Divers in Australia as so far been limited to discussions about producing decompression tables for a 82.75/17.5 heliox FGG111 semi-closed circuit dive to a maximum depth of 325 fsw (95 msw) for a maximum of 40 minutes. Dr Hamilton has agreed, in principle, to do so.

Rob Cason

Telita Cruises
PO. Box 303, Alotau
Papua New Guinea
April 20th 1992

The Editor,

Des Gorman's entertaining editorial assumes that all high tech diving is oxy-helium or trimix diving, and uses cases of disastrous experiences with these gases to justify SPUMS campaigning against recreational high tech diving. However "Technical Diving", as it is more commonly called, is more likely to manifest itself by recreational divers using enriched air, not oxy-helium or trimix, and also includes the wonderful and dramatic dives, using air, that were recently made in caves in Western Australia. Is SPUMS going to campaign against these as well?

Dr Gorman is completely correct that risk acceptance must be preceded by education, and the recreational diving industry has already devised courses for this purpose, highly responsible of them, surely. However some of his other comments had me in stitches. "Recreation should be fun" indeed, does SPUMS think perhaps that ADVENTURE should not be a part of life? Fun to me denotes some frivolity, and I believe that the phrase “Diving is Fun” has done enormous damage to recreational diving. As you well know, all diving requires a disciplined and responsible attitude. Promoting diving as fun attracts the WRONG people to diving classes. But the real corker is the comment about the “psychology and mentality involved” in undertaking high risks. I agree that the vast majority of diving “accidents” are caused by a failure to recognise, or a decision to ignore, the real risks of a dive, a condition I call “stupidity”, a common mental state. It could be a function of low intelligence but is MORE OFTEN DEMONSTRATED BY THE CASUAL ATTITUDE OF DIVERS WHO THINK THEY ARE HAVING FUN (like going to a party) instead of being serious about the dive. Ironically this is a condition THAT IS COMPLETELY IGNORED IN YOUR DIVING MEDICAL publication included in the same issue.

I note that Dr Gorman writes that SPUMS will not oppose any government who consequently legislates some limit on (high tech) recreational diving. I am one of those Australians that he mentions, that believe I should have freedom of choice and no Government intervention, and I am quite prepared to pay my own way, as long as those injured in other adventure or sporting activities do the same. The reason I oppose any legislation is that the vast majority of regulations assume that I am either criminal or stupid. It is about time that some recognition be given to the fact that there ARE stupid people who should not be diving or whose diving should be limited to very low risk dives. Then there are others who can learn and who will be able to conduct safely dives of a much higher risk. Education is preferable to legislation. I am admitting that some will not benefit from the sort of highly technical programs that will be necessary, so why not exclude them instead of everybody ? The first place in the screening process is the diving medical, why has stupidity been ignored ? SPUMS is vitally concerned with physical fitness to dive, are you not concerned about mental fitness as well ? Is this too hard for the diving medical community ? Are psychological tests excluded ? What about intelligence ?

SPUMS believes that all candidates for diving should have a medical examination by a physician qualified in diving medicine. The rest of the world (or almost) believes that the diving instructor has the ability to make the first determination, from a questionnaire, as to whether a prospective student is medically fit to dive and only if some contraindication is indicated on the form does the instructor refer the candidate to a doctor. If SPUMS believes that instructors are not qualified to make this determination, well that is fine with me, BUT, at the end of the course the instructor is expected to make an evaluation of the mental state of the candidate. NAUI, to its great credit, uses the phrase “would I let my loved ones dive with this student” as a final determination as to whether the diver should be certified. Nevertheless instructors are really not qualified to determine a prospective diver’s mental state.

Having the “right stuff” for diving, and ESPECIALLY Technical diving, is not only a question of physical fitness but also of MENTAL fitness. All legislation does is restrict the lives of those who do have the special abilities necessary for SAFE participation in higher risk activities. Higher risk does NOT necessarily mean greater danger. It does mean that more ability and training is required. Arbitrary limits, such as the 40 m “safe depth limit” are an insult to intelligence. Many divers are unsafe at 10 m !! Are ALL divers unsafe at 41 meters ? Why do the Project Stickybeak reports never have any reference to the IQ or the pre-dive mental state of victims ? Is this a plot to ensure that intelligent people are not allowed to do anything in their leisure time that a stupid person cannot do ? I put it to you, seriously, that SPUMS has ignored the mental health aspect of fitness to dive. Can I have a response please, from anyone?

I do not believe that any of my 6,000 odd dives have been dangerous except as I note in the next paragraph. The reason is that I have assessed the risks carefully and, to the best of my ability, knowledgeably, and have only dived where I was confident that I had the skills and knowledge necessary to overcome the risks and make the dive safe. The reason for my assuming the risks, is NOT the risks themselves, but because I LOVE the underwater world. I have an enormous desire to see what and how creatures live their lives 100 meters down. The reason I have not seen them is because I do not have a way of overcoming the increased risks of being that deep. But if technology produces a means for me to do this, so that I am satisfied that the dive is safe, I will be there. If you really have to pass laws to save the public purse why not try to ban smoking or anal sex? Or, even better, pass a law banning regulations. Then we could put the bureaucrats on the dole where they will do less harm and earn a wage more appropriate to their abilities, and really save money to spend on new hyperbaric facilities? It’s all right, I know the answers, but can we spare diving please ? I am in favour of better screening of student divers, of much better, and graded, diver education and training, and probationary periods for new divers. But always EDUCATION never LEGISLATION.

Some of the risks that are very hard to determine are those forced on me. If I dive in Queensland, Australia, by legislation I have to dive with a buddy who may be unknown to me. The dangerous situations I have been in underwater were ALL caused by other divers. A recent survey I conducted revealed that MORE (experienced) divers were put into dangerous situations BY THEIR BUDDIES than were “rescued” by them. Legislation is NOT the answer to ANY of diving’s problems. In fact I have to wonder at the psychology and mentality involved with those that propose it, or those that do not actively oppose it.

Bob Halstead

PULMONARY BAROTRAUMA DURING POOL TRAINING

Diving Medicine and Assessment Centre
4 Dodson Avenue
Milford, Auckland 10
New Zealand
19 February, 1991

The Editor,

I wish report a second case of pulmonary barotrauma and cerebral gas embolism sustained whilst undergoing scuba training.

An 18 year old female exchange student from Canada ascended rapidly from 4.5 m in June 1991. She had been having difficulty equalising her ears, inflated her buoyancy compensator, and shot rapidly to the surface. At the surface she felt short of breath, had chest discomfort and was dizzy and tired.

Her GP recognised the problem was diving related and referred her on for my assessment. Assessment was particularly difficult as she presented as a lethargic, giddy, young adult whose cerebral function was quite inappropriate for an exchange student when tested with memory, simple mathematical problems and general discussion. She was short of breath with some chest discomfort. She fell to the right with the Sharpened Romberg test and had some 2-beat nystagmus laterally. She was sent to the Royal New Zealand Navy recompression chamber for a trial of therapy. Both her impaired mentation and her balance improved after the first treatment. She was discharged following a further three treatments, at which time her mental fucntion was regarded as normal.

This case demonstrates the difficulty of assessing a young person whose mental function is suddenly impaired, as judged by her friends (her family was not available). After recompression therapy her mental function, balance and nystagmus all returned to normal.

Allan F N Sutherland

THE OVER-DIVED SYNDROME

Diving Medicine and Assessment Centre
4 Dodson Avenue
Auckland 10
New Zealand
19 February, 1992

The Editor

Having now identified two air emboli sustained in scuba diving training pools during rapid ascent from 3.6 m (12 ft)[1] and 4.5 m (15 ft)[2] respectively, I wonder how frequently such significant incidents occur and how many go undetected, yet have permanent sequelae?

In the group of severe diving accident cases[3] that I have followed up, and in sports diving instructors, I have noted a high incidence of medical, neurological and intellectual changes. The intellectual changes have been documented in the reported cases, by Dr Dorothy Gromwell's Post-Concussion Clinic at the Auckland Hospital. No such intellectual function assessment has occurred on the sport diving instructors, although, like myself, this much dived group have soft neurological changes with almost universal hearing difficulties and tinnitus.

It is my contention, for which I invite informed discussion, that scuba diving incidents such as rapid ascent, can cause minor changes, which subsequently compound, affecting neural and other tissues, leaving many middle-aged, over-dived sport divers and sport diving instructors, with minor permanent medical disabilities. I propose the name "The Over-Dived Syndrome".

Allan F N Sutherland

References

1 Robinson P and Sutherland AFN. A case of cerebral gas embolism. SPUMS J 1987; 17 (1):14-15
2 Sutherland AFN. Pulmonary barotrauma during pool training. SPUMS J 1992; 22 (2): 89
3 Sutherland AFN. Diving accident cases treated at HMZNS PHILOMEL recompression chamber in 1988. SPUMS J 1990; 20 (1): 4-5

BOOK REVIEWS

DIVING AND SUBAQUATIC MEDICINE (Third Edition)
Carl Edmonds, Christopher Lowry and John Pennefather
ISBN 0-7506-0259-7
Butterworth-Heinemann, Oxford
RRP $A 95.00

It is an overdue pleasure to read the third edition of this well known Australian textbook. It is a much larger book than the last edition. This is the only disappointing feature of the new edition, it is heavier and more awkward to hold. The increase in size is mostly due to the use of a larger type face, which I must admit makes it easier to read.

The book has been extensively revised and now has colour plates for some of the more difficult things to show in black and white. There are many new illustrations and most of the old favourites have been retained.

One of the most obvious changes is the large number of case reports scattered through the text. These clinical tit bits illuminate and drive home many lessons. It is difficult to think of anything that would be of use to a clinician which has been left out. I have not had any success in this task.

Although the price appears high it is (after allowing for inflation) about the same cost as the first edition 16 years ago. Like that book, this one is well worth the price. It should be on the bookshelf of every doctor who dives, as well as that of every diving doctor, and in every hospital and medical library.

John Knight

MAN IN THE SEA
Volumes 1 and 2
Editors Yu-Chong Lin and Kathleen K.Shida
Best Publishing Company, Flagstaff, Arizona
RPP Vol 1 $US 32.00, Vol 2 $US 30.00

These two books are the result of the Second International Symposium on Man in the Sea, held in November 1988 in Honolulu. This review is a little late as the books were published in 1990. The First International Symposium on Man in the Sea was held in 1975 and the proceedings were a most interesting and wide ranging book.

This symposium, with many contributors, covers saturation diving in volume 1. The sections deal with compression regimes, the effecs of different gas mixtures on HPNS, pressure adaptation, saturation diving by different organisations and countries, decompression, bubble formation, decompression illness, Doppler evaluation of decompression tables and finally the future of manned diving.

The second volume is devoted to sports diving, hyperbaric medicine, manned submersibles and finishes with a paper on the future of man in the sea. Most of the papers in the sports diving section are on physiology, especially that of breath-hold diving. The last paper in this section is a comparison of the safety records of novice and experienced Japanese divers. Two thirds of the accidents occurred at depths of less than 10 m. The authors attribute some of the blame to panic induced by ear pain, an interesting surmise. Of the 104 deaths, 32 were on their first ocean dive and another 15 died less than a year after their course. The hyperbaric medicine segment covers everything from space-flight, compressed air work and hospital facilities to diving accident management in remote areas, a paper by Carl Edmonds, and on to the post-mortem room. The three papers on manned submersibles are about deep exploration rather than oil field work.

Most of the papers are easy to read and all are informative. At the advertised price they are a good buy for the physician interested in diving medicine.

John Knight

DIVING THE RAINBOW REEFS
Adventures of an Underwater Photographer
Paul S.Auerbach, M.D.
ISBN 0-87850-072-3
Mosby Year Book, Inc. St Louis,Missouri.
Review copy from Mosby-Williams & Wilkins Pty. Ltd.
RRP $ 79.95

In this beautiful book Dr Auerbach leads his readers rapidly through the problems of becoming a diver and an underwater photographer and then takes them round a wide spread world.underwater His pictures range from the Philippines, through Micronesia, the Galapagos Islands, the Caribbean, the Red Sea, Palau, Fiji and the Coral Sea. The 251 colour photographs range from the excellent (the majority) to the ordinary. The text is first person travel journalism and seems to be aimed at the non-diver to convert him or her to diving.

Australians can find a number of equally beautiful, and more informative, books about fishes and corals in the Indo-Pacific region in their book shops. But for a round the world set of underwater photographs, not taken by a full time professional photographer, one would have to go a long way to equal this book.

John Knight

SPUMS ANNUAL SCIENTIFIC MEETING 1991

A TRAINING AGENCY PERSPECTIVE ON DES FUNDING AND OTHER TOPICAL ISSUES

Terry Cummins

Introduction

The diving community needs to have a stable and workable relationship between instructor agencies and hyperbaric medical personnel.

In the past there have been frictions between the instructor agencies and the diving medical fraternity. Some of those frictions still exist today. It is important that we identify these potential problem areas because it is not desirable for us to slip back into what Dr Des Gorman once described as “instructor bashing” by doctors, or conversely, instructors feeling that diving doctors are individuals who need to be viewed with scepticism.

Areas of Concern

There are five major areas of concern that need to be addressed. With a clear understanding of these problems, or should I say of the misunderstandings they create, we will reduce possible friction between instructors and diving doctors generally and create the necessary working relationship we all desire.

Please remember my topic includes the phrase “a training agency perception”. It is important to realize how instructors feel about major issues, even if their perception is not always based on fact.

I feel that it is equally important for doctors involved in hyperbaric medicine to understand that some friction does exist between the two groups, that it is unhealthy and that it needs to be cured. To do this successfully one must first understand how instructors and some instructor agencies feel about some topical issues.

In presenting this topic it is acknowledged that some of the content will not be popular with some medicos, and I expect a colourful discussion at the conclusion of the paper. One could say I am prepared to stick my neck out to bring some of these issues into the light so that a more favourable era may emerge.

Future funding of Diving Emergency Service (DES)

With the collapse of the National Safety Council of Australia (Victorian Division) there was an immediate need for funding. The instructor agencies, the Commonwealth and South Australian Governments and elements within the medical community provided funding for DES.

The major Australian instructor agencies, the Federation of Australian Underwater Instructors (FAUI), the National Association of Underwater Instructors (NAUI) and PADI Australia responded by making equal monthly grants to DES. Grants were also forthcoming from the Dive Industry and Travel Association of Australia (DITAA) and PADI U.S.A. Later this was altered to a system by which each agency supported DES by that method which they saw as most appropriate. For example, earlier this year PADI Australia made a $3,000 grant to DES while reserving the allocation of further funding until later in the year. FAUI currently has a policy of paying a percentage of every diver certification fee to DES. Neither NAUI or SSI have made recent contributions based on reasons they feel are valid.

The diving medical fraternity needs to realize that both instructor agencies and the members they represent expect that the funding of DES is not left entirely to the instructor agencies and the Commonwealth Government. It is acknowledged that individual medical identities have personally committed a lot of time and effort to DES, however the instructor agencies think it is appropriate that the diving medical community in general make a larger contribution.

This should not be perceived by the diving medical community to be an attack on them from the instructors in the field. Indeed as a group it would be fair to say that the instructor agencies feel the contribution made by the Commonwealth Government to providing special facilities should be much greater. This is a particularly good argument when an observation is made of other forms of recreation and the relative stress they place on medical facilities, retrieval services, Medicare and private health funds.

Economic forces affecting dive retailers means that an endless stream of money has not flowed, and will not flow, from the “industrial side” of the diving community to DES. As a result of these economic forces and other factors, additional sources of income will need to be obtained to sustain the facility.

To develop new sources of income, DES and its associates must realize the sensitivity of marketing products that have traditionally been the realm of the training agencies. It is the feeling of the training agencies that products, including the marketing of the Defence and Civil Institute of Environmental Medicine (DCIEM) dive tables, are not a good choice.

Movement into this area of fund raising will result in the training agencies viewing DES as a competitor because all agencies have their own dive table in one form or another. Clearly agencies do not donate money to competitors. Income from training agencies could immediately cease if this problem was allowed to develop and the net result would be a loss of agency support for DES. Already this is the stand of SSI and funds will not flow from this organization unless the DCIEM debate is resolved. Some feel that this debate is resolved. However while a close relationship between the Australian Patient Safety Foundation (APSF), Divesafe and DES exists it would appear problems will continue to occur.

The sale of a dive table as a source of raising revenue for DES has another downside because, apart from the competitive aspect, it could follow that DES would be supporting, say the DCIEM tables over the PADI Recreational Dive Planner, the FAUI Newway Table or the U.S. Navy derivatives used by both NAUI and SSI. This may lead to an argument over which table is the best.

In summary, it is not acceptable to the training agencies that the DCIEM tables be promoted by DES or any of its associated organizations such as the Australian Patient Safety Foundation and Divesafe, since this will unnecessarily lead to suspicion regarding competition between tables. It is very clear that the right table to use is purely a matter of opinion and is based on the factors the user feels are important and the use for which it is intended. Therefore, in relation to tables and their promotion, DES must be apolitical or they will be perceived as a competitor in this area by the agencies. I am sure the training agencies would not like to see this problem develop further. Well, where will the money come from?

Other products or services must be found to raise funds. Certainly DES "membership" could be one source of income. This method of raising income or funds has already been utilized by the Divers Accident Network (DAN) in the U.S.A.

The instructor agencies may be prepared to help in this area. For example, PADI has an international agreement with DAN to publish a DAN membership information sheet in all its publications. This ensures a large world-wide promotion of DAN membership. One should note that PADI Australia has followed this policy in all locally produced publications including the production of the Openwater Manual which also references DES. Linked to the DAN/DES membership idea is the consideration of offering a diver insurance policy.

Also in relation to DES, it is important to realize that the training agencies want their relationship with DES to be a two way experience. In return for any funding support the training agencies give DES, they would like to see something in return.

NAUI has formally asked DES to give them some indication of the benefits NAUI will derive from funding the facility. NAUI's perception is that a satisfactory explanation has not been forthcoming so no funding has been provided in recent times from this agency.

The problem is that instructors do not feel they put the patient in the chamber in the first place, so why should they meet the cost, either directly or indirectly. Instructors do however, acknowledge the important service DES provides, so they are prepared, at best, to provide some of the support and funding.

It would be fair to expect a number of benefits would flow to the instructors and instructor agencies from their involvement. This may include but, is not necessarily limited to:-

Access to reliable DES data. It would appear that Dr Chris Acott is currently working towards this goal.

DES to be apolitical in all aspects of its operation and operate as a source of professional consultation for the industry participants.

Opinion statements that are perceived to be SPUMS Policy

Somewhat related to the DCIEM dive table issue, the instructor agencies have a problem in that the opinions of high profile diving medical personalities are generally perceived as policy statements of SPUMS. The same applies to remarks by staff at hyperbaric facilities being regarded as official statements on behalf of DES. On more than one occasion high profile members of SPUMS have made what some describe as sweeping statements in relation to the best dive table or the best instructor system. In some cases these comments have fallen just short of legal action.

It is no secret that some individuals have very fixed ideas on diver training, the right dive table to use or the make-up of a diver medical. Although I am not suggesting that individuals are not entitled to their opinion and that opinion cannot be expressed, what I am suggesting is that there is a right way to go about that procedure. One way is to ensure that if one has an opinion that one is careful not to suggest that it is the opinion of SPUMS, unless it really is the collective opinion of SPUMS. SPUMS can assist in this process by having formal policy statements on vital issues. This would clearly illustrate the difference in opinion of a member as opposed to the Society.

The best way to voice opinion at this level is to offer a paper at next year's SPUMS Conference and so give the industry a chance to discuss topical issues without involving the public, which only leads to our industry being viewed as factionalized.

It is important to realize that a major objective of my presentation is to gain a level of co-operation between the medical fraternity and scuba instructors. Because of the efforts of some, this is not happening.

Another way to reduce friction when varying opinions exist, on what is proving to be an impure science, is not to publish articles like the one from which the following quotation is taken, written by a "high profile expert".

"In previous articles I have been ever critical of many recreational diving operations in this country and overseas. With the odd exception (such as those at Heron Island and a very few other centres) I felt that my criticisms were, and in many cases and still are, fully justified. Proof of these beliefs was evidenced by the steady flow of injured divers to my surgery in Brisbane, as well as to other diving medical colleagues in Sydney and elsewhere. These all confirm similar injuries to those I see. This history of the diving activities preceding most of these injuries, and the subsequent care shown by many of the Diving Operators leaves one in no doubt as to the gross deficiencies of the diving industry in Australia today."[1]

Notice how this article directly implies "the operator" is to blame for a diving injury. By reference to accident statistics it is clearly shown that very few if any accidents occur in training or under direct supervision of a diving professional.[2] You can well ask why bash the operator if one of his clients has a problem.

The damage articles like this do is sometimes irreparable or at best it takes years to remove the bad feelings caused between medical circles and instructor groups.

Unfortunately, dive stores see articles like this as a return to "instructor or dive store bashing" by the medical fraternity generally. They will also see it as a negative promotion of their services to their customers and that really hurts ! Really what data exists to support this individual's single impression? Unfortunately, this type of article gives the general diving public the impression something is really wrong in the diving industry. Is this really the case ?

Accident referrals

The increased availability of recompression and hyperbaric treatment facilities in the last few years has led to a unique problem.

From an instructor's point of view, the availability of treatment facilities and the subsequent treatment of individuals, particularly those with symptoms of DCS, may be working against instructors politically. Several reports from the field indicate that individuals treated in chambers who were subsequently diagnosed as not having DCS are used in data to imply diving is becoming more dangerous than it was in the past. An example of a poor interpretation of reality is that if DES calls have increased so diving is becoming more dangerous. Many would argue that the number of calls may continue to increase regardless of the safety standards as more divers are encouraged to use the full range of services offered by DES.

Inaccurate data also exists as we see when a number of treatments or admissions are quoted without reference to whether they were finally proven to be necessary or useful to the patient. Indications are that at least at the Royal Adelaide Hospital attempts are made to ensure the data is kept clean.

The instructor agencies would welcome the idea of removing those individuals that are later diagnosed as not having diving related symptoms from treatment statistics. Similarly we would like to see data not include hyperbaric treatment of patients for non-diving related complaints, such as gas gangrene.

Currently all instructor agencies have their members advise students and divers to seek out DES and report for treatment if any symptoms develop after diving. This is based on the idea that if in doubt, and the facility is there, use it.

We would not like to have a shift away from this current policy, but it appears that if instructors or dive schools are at all suspicious of the political outcome of seeking treatment or if they feel that they are going to look unnecessarily foolish, they may move towards the unfavorable policy of suggesting presenting for treatment only when you are sure you have symptoms. It is also important to note that the "instructor bashing" phenomena addressed earlier is exasperated by this situation.

It is unfortunately a feeling amongst some instructors that elements within the diving medical community have attempted to make political mileage or have increased budgets out of genuine attempts by divers to seek professional medical consultation and possibly treatment.

There is another aspect to the instructor bashing or "blame model" as I call it, which is worth discussion. As mentioned earlier, rationale of the blame model is based on the very poor assumption that whenever there is a diving accident, that it is the "fault" of someone.

Traditionally, diving medical sources have immediately looked towards the quality of the instruction, the quality of the divemaster services or the quality of the dive store. Although under some and only some circumstances, this may be a valid approach, the more common cause of diving accidents is "diver error". Diver error can originate from many sources and in fact is as varied as the individuals who are involved.

Unfortunately, the total focus of the blame model is on the dive operator and this is invalid, because clearly the majority of dive operators in this country are extremely professional and know only too well that they live in a world where it seems to be the norm to seek blame someone. The catch word to illustrate this is “duty of care”. In Cairns, Queensland, over 3,300 dives are carried out each week. This reflects an outstanding amount in diving activity. Some elements would like us to think that this area is also the scene of massive standards violations and unprofessional behaviour. Using the objective mind this is simply not the case when one compares diving activity to the number of accidents and then exclude those due to contributing factors outside the operator’s control.

In no other recreational activity is this phenomenon so pronounced. It is indeed unfortunate that a few diving medical personalities, competing dive stores or instructors need to create such a negative view of our industry. Those of us that have been involved in observing trends over the past few years are often left wondering why the blame model does not exist in football, sky diving, snow skiing or other recreational areas. Is it just the type of people our industry attracts?

We are further confused when snow skiing and football have a much larger number of serious accidents than does scuba diving, but attract no apparent attention from either the media or medical or participant circles.

It seems to scuba instructors that if one breaks an arm or leg playing football, one is a real man or a hero of the team, but if one has a diving accident one is stupid and irresponsible. Have we all in our own way contributed to this phenomenon? What is really the difference between diving and other recreational activities?

Also be aware that, while we all run around trying to blame someone for what may have simply been an accident, we may run the very real risk of missing the entire point of accident analysis. That is, we may miss placing emphasis on correction and prevention while we are preoccupied with placing blame. This question really needs to be answered seriously before our industry can really grow and allow us all to realise our own goals.

Medical input at Standards Australia

Standards Australia has representatives from both SPUMS and the instructor agencies. Currently the diver medical is being debated and several major disagreements have emerged. Since the exact content of that debate may be addressed in other papers at this conference, I do not want to address individual items. I do, however, want to address some important issues generally. Who should be authorised to conduct diving medicals is a hot issue with instructors.

Clearly the trained number of medical staff to do diving medicals is currently out of balance with diving applicants and the market place.

It would be extremely difficult to assume that the demand for diving medicals could be met by those with specialized training in hyperbaric medicine at this time.

In 1990, nearly 100,000 individuals passed through dive schools in Australia in total. This means that scuba instruction is a $30 million per annum industry in Australia alone. Most (70%) were at the entry level, requiring diving medicals. This is approximately a $5 million per annum industry.

The instructors in the field will not support the concept of medicals being conducted by those only with experience in hyperbaric medicine until medical personnel of that calibre are freely available. Similarly, given these numbers, it is doubtful whether we will reach a position where this will be a practical option for several years, especially in remote areas and on resort locations where a relatively large amount of instruction is currently taking place. Doctors will have to also ask the very real question of whether the medical part of the industry is growing at the appropriate rate to ensure this debate will not continue. Under the present model the ball is very much in the court of the diving medical fraternity to ensure that a suitable number of doctors are trained in the next two years.

The instructor agencies are therefore reluctant to support the SPUMS stand on this issue and this should not be interpreted by physicians to be a movement away from safety. In fact, the data shows that medicals conducted by GP’s may be sufficient, especially if a form is established with suitable guidelines. Again we are left asking what makes diving so special. If a GP has a problem in providing a diving medical, he or she will refer it to a specialist. Why in diving are we assuming the professionalism of the GP is such that he will not follow the same practice as we expect him or her to follow if the GP was viewing another specialized area?

In summary, some instructors feel that some individuals within the diving medical fraternity have developed specialised practices which they seek to protect and that they have used their public profile to have more emphasis on this issue than it possibly deserves. Instructors would agree it is desirable to have doctors with specialised training, but at this stage it is impractical, based on current demand and the availability of specialists.

Non-disclosure

It is clear that several of the diving deaths from 1980-86 occurred due to medical conditions. It is the feeling of many instructors that regardless of the medical, regardless of the quality of the physician applying it, this will continue due to “non-disclosure”. Clearly our biggest problem is not who administers the medical but that the information that is gathered is accurate. Some doctors seem to have the opinion that instructors should go to unbelievable lengths to ensure the medical is carried out correctly. Similarly, instructors feel that it is not exactly fair when some elements in the diving medical fraternity suggest instructors should override the expertise of a GP in relation to assessing the fitness of the individual to dive.

One needs to ask the question, how many of these accidents would have been avoided if a specialist had have conducted the diving medical? Indications are that the most experienced physician has little chance of detecting predisposing conditions if the patient is not prepared to be honest and assist in the examination.

This type of comment has been printed in some dive magazines recently.

“If such an instructor then permits the diving candidate to be examined by a doctor (known to possibly have little experience or expertise in diving medicine) and then that instructor accepts the diving candidate as passing the fitness examination (without questioning the validity of such exam), then the instructor could well be equally culpable by law for any litigation under this “duty of care” legislation”.[1]

Is this a true legal interpretation of the reality of the situation or is purely one opinion. It is not the opinion of our legal counsel and I respectfully suggest that it would not be the opinion of yours.

How should the average scuba instructor would interpret this article? More importantly how do doctors feel the average GP would interpret this article ?

At best, this type of article causes mass confusion amongst the instructor community.

Money issues

Who gets paid to conduct a medical ? Who gets paid to train a doctor to conduct a medical ? Who gets paid to teach scuba ? Who gets paid to teach scuba instructors ?

I ask who really cares ? We all get paid one way or another. Some instructors are concerned that it is being said in some circles that instructors wish to make money at the expense of safety. Money and the cost of medicals is a non-issue. A $60 medical in most cases will make little difference to marketing a $400 scuba course. The real debate is whether the medical is at all necessary in the first place, whether screening is a suitable alternative and whether leaving out the GP is overkill.

Instructors know that if instruction is unsafe, instructors are out of business. We certainly acknowledge our duty of care. We also acknowledge that the only way to prevent accidents in any sport is to stop people from participating. Unfortunately, to instructors, that seems to be the option some within the diving medical community are pushing.

Conditional medicals

Despite calls from all the instructor agencies, some doctors still insist on granting “conditional” medicals. It is a major frustration to the training agencies that some diving medical doctors insist on issuing conditional medicals or alternatively re-writing the course syllabus to suit a patient. I say patient deliberately because if they are not fit to dive they are likely to be a patient at sometime or other. It is important that to all those performing diving medicals, realize that courses cannot be customized to suit medical conditions. This includes courses for the disabled. Special training techniques can be employed for this group, certainly we can take more time in the training process, but they too must conform to the course objectives facing all students. If we cannot guarantee that the medical condition of the applicant is such that they can meet the performance objectives of the programme then they cannot be accepted.

Clearly if a medical conditions exists, it is the responsibility of the doctor to advise the applicant accordingly.

Some frustration also originates in the failure of some doctors to break the news to his patient that he or she cannot dive. Unfortunately this reluctance comes at the same time that it appears doctors are vocal in calling for tighter control. It seems that these doctors would prefer to leave it to the instructor to refuse access to a dive course than accept the responsibility themselves. This problem is also reflected in the previous magazine quotation.

Strangely it seems that the physicians offering conditional medicals are the most outspoken on diving medical issues. Common “conditional medical” phrases we still get include:

“10 metres maximum depth”
“18 metres maximum depth”
“Only dive to half the No-decompression diving limit”
“Only under the control of an instructor”
“Only if under the control of an experienced diver”
“No free ascent practice”

All are unacceptable because they cannot lead to certification of the diver.

“No free ascent practice” is an interesting one because I am aware that no agency includes this in their training. Maybe reference to instructor manuals and a clear understanding of out of air emergency drills offered by the various instructor agencies would clear this one up once and for all.

The instructor agencies would appreciate it if their members did not become the focus of potential debates with prospective students on fitness to dive. That surely is the domain of the patient and the physician.

At the beginning of this presentation I stated that some of the content may not be popular with all those attending. It was my intention however to create healthy debate within the arena of a professional conference, rather than allow totally unnecessary misunderstandings to exist. If we do not know clearly what the problems are and address them accordingly, we will all suffer from poor information.

The instructor agencies generally are very conscious of their obligations to safety. What we now want is to commence a new era where diving doctors, instructor groups and other elements within our industry can work together for a common goal.

Only by the inclusion of other dive industry participants in the SPUMS Conference can we ensure that is discussed becomes useful. For example, Dr Chris Acott can deliver as many papers as he likes for the next 10 years on incident reporting but if those reports are not used by instructors, dive stores and equipment manufacturers to make constructive changes his efforts are unfortunately nothing more than an academic exercise in futility.

I see the five major areas of potential conflict I have outlined as a starting point for this new age of co-operation. The benefits to us all of creating sound working relationships are immeasurable. Let us start building on it today.

References

1 Thomas RL Queensland's new 19989 diving regulations. *Underwater Geographic* 1990; Number 31

2 *Diving Accident Management In Australia.* PADI, 1988

Terry Cummins is the Chief Executive of PADI Australia Pty. Ltd. His address is PADI Australia Pty. Ltd., Unit 1/1-7 Lyon Park Road, North Ryde, New South Wales, 2113, Australia.

The Committee of SPUMS considered that Mr Cummins was misinformed on a number of topics and authorised Dr David Davies, the Education Offier, to write the reply which follows.

A DIVING MEDICAL VIEW OF A TRAINING AGENCY PERSPECTIVE

David Davies

The paper,[1] presented by Mr Cummins at the SPUMS Annual Scientific Meeting in the Maldives, was most interesting as it brought into the open the innuendo and misinformation circulating in the diving community that has been the bane of diving medicine for some years. I have been asked to try to explain why and where Mr Cummins' perceptions vary from reality.

It has been stated before but obviously needs to be repeated that **only the President and the Honorary Secretary of SPUMS may speak on behalf of the Society**. In some circumstances, the Executive committee may nominate a specific person to be the spokesman on a particular subject at a specific time.

The article quoted from Underwater Geographic[2] is the personal view of a prominent Queensland doctor and should in not, in any way, be construed as being either SPUMS policy or even the beliefs of many members of SPUMS. In fact, a number of SPUMS members took exception to the sentiments expressed in that article.

The problem of conditional medical certificates has been with us for a long time. It is a consequence of the diving medical being done by a doctor not properly trained in diving medicine. Many of the conditions imposed reflect a lack of understanding of the physics and physical requirements of diving. This problem could be overcome by insisting that all diving medicals are done by doctors with the appropriate training. It is unfortunate that the CS/83 Committee of Standards Australia saw fit to remove this requirement[3] from the proposed standard for recreational divers. There is a reactionary element in the medical community with the misguided belief that once a doctor graduates he is trained for everything. The attempt of the Australian Medical Association to be everything to everyone led to the AMA representative on the CS/83 Committee being instructed to vote against compulsory further training of doctors doing diving medicals.

I believe that the training organizations, and the diving instructors themselves, can help with this problem by suggesting to their students that they attend, for their diving medical, only those doctors with the appropriate training. It does not take long for an instructor to ascertain which of the doctors in his area supply the best service to his students. By so doing, the instructors can exert pressure and stimulate their local doctors to seek the necessary training. SPUMS has no way to apply such pressure.

Mr Cummins appeared to believe that a basic training course in diving medicine turns a doctor into a specialist in the field. Nothing could be further from the truth. The basic course at the School of Underwater Medicine lasts for two weeks, in Adelaide it takes a week, and in Queensland it is conducted over a weekend. These courses provide an introduction to the subject and what to look for, and why, during a diving medical. They explain why conditions such as asthma, epilepsy and congestive cardiac failure are not compatible with safe diving but they do not cover the intricacies of treating a severe decompression illness.

The specialists in diving medicine are relatively rare in Australia. Holders of the Diploma in Diving and Hyperbaric Medicine are the only people recognised as Diving Medical Specialists by SPUMS. Almost all are attached to hospitals with recompression facilities and it is on their shoulders that the burden of treating injured divers falls. They are available for consultation in difficult cases and if problems arise. Very few of them do routine diving medicals.

We all appreciate that there are areas of the country where there are no doctors with training in diving medicine. With the amount of diving that is being done in Australia it is inevitable that every GP at some time in his career will encounter a patient who either wants to dive or has been diving and now has a problem. Dr Edmonds' paper[4] reporting the lack of knowledge about diving medicine in a survey of Queensland GPs confirms the need for instructors to exert pressure on their local doctors.

When the National Safety Council (Victorian Division) collapsed the funding of the Diver Emergency Service (DES) needed urgent CPR. In the heat of the moment a compromise was engineered by Des Gorman which required the marriage of DES with the Australian Patient Safety Foundation (APSF). Among its many fund raising activities the APSF has included the sale of products such as the DCIEM decompression tables. Without entering into a discussion about the merits of the various tables it is fair to say that the experimental evidence behind the DCIEM Tables is vastly more than that behind any other. They also appear to be safer.[5] Doctors have difficulty understanding the belief that making available a set of tables that is not promoted by any training organization can be seen as competition when no advertising of these tables is undertaken.

Recently the funding arrangements of the two organizations has altered enabling the temporary marriage to be dissolved so they are now completely separate entities. The suggestion that DES is in direct competition with the dive organizations no longer applies.

During the crisis, SPUMS and some of the members of the Executive Committee were the first to make significant donations for both time and money to enable DES to continue. In addition, SPUMS has recently made a further donation to support the DES network. To suggest that the medical profession is not doing enough to support the DES network is both inaccurate and misleading.

Mr Cummins states that the most common cause of diving accidents is "diver error" and that is certainly the impression one gains when we treat these patients in the hyperbaric chamber. The paper by Wilks and O'Hagan[6] demonstrated that divers do not fully understand how to use tables and often have to rely on the divemaster to calculate their repetitive dive times. Every failure to use the tables correctly is a failure of education and of reinforcement of that education.

Very few divers have problems during their basic course when they are under close supervision, the learning curve is steep and they are concentrating intensely. However, once "trained" and left to their own devices many run into problems and forget their basic instruction. It is these recently qualified divers who make up the bulk of those presenting for treatment at our recompression facility in Fremantle. Is this a deficiency of the education, the training organization, the instructor, the student, or is it a reflection on the brevity of the course? At the Annual Scientific Meeting in 1991, Glen Egstrom spoke of the need to overlearn each skill until it becomes an automatic reflex. Such training is not possible with the brief courses, especially resort courses, that are being offered by all the training organizations.

Most diving doctors consider that, as instructors train divers and most diving accidents are due to human error, it is fair to say that these human errors may well be due to inadequate training, which reflects on the standard of teaching. This is the view medical educators take to avoid repetition of medical accidents.

It seems unreasonable to me that, whenever a funding crisis occurs, everyone expects that the government will step in and pick up the tab. I would prefer to see the diving community helping itself by placing a levy on every trainee diver (say $10.00) at the beginning of every course or at the time of certification. In addition, a levy of $0.50 could be put on every tank refill. The proceeds of both these levies would go to support DES. Neither impost would make a significant difference to the cost of a dive or a course and the money would be contributed by those actively diving and therefore most likely to need the services of the DES organization.

Membership of DES could well be another source of income as it is with the Diver Accident Network (DAN) in the United States. There, such membership automatically includes insurance cover for retrieval and treatment of diving accidents. Currently Dr Acott is negotiating with the Australian insurance companies for a similar arrangement. Unfortunately the local insurance companies are demanding about twice the US premium for a much lower standard of cover and this is unacceptable to the DES negotiators.

Despite what Mr Cummins perceives, hyperbaric units are not installed for the benefit and convenience of the diving community. In fact, divers make up only a small proportion of the workload in a civilian chamber. At Fremantle[7] for instance in 1990, 41 divers received 119 treatments in a total of 1808 patient treatments, i.e. 6.6% of the total workload. In Adelaide[8] over the same period, 20 divers required 69 treatments in a total of 792, a strike rate of 8.7% of the total workload.

In the reports from both these units, the figures for divers are quite separate from the other conditions treated. To suggest that treatments for divers and non-diving conditions are grouped together to boost the figures is grossly misleading.

I am grateful to Mr Cummins for bringing these problems into the open where they can be discussed. The problems have arisen because of a lack of communication between the agencies, the instructors and some of the outspoken diving medicos.

After a week of being incarcerated with the SPUMS group in the Maldives last year, both before and after he presented his paper, I believe that Mr Cummins returned with opinions significantly different from those he presented in this paper. All these problems were discussed and many points of mutual agreement were reached. If he was now asked to present such a paper I expect its content would be vastly different. Unfortunately I fear that others may still harbour his original misconceptions, which is why this reply has been written.

There has always been a standing invitation to all Associate Members of SPUMS to attend the Annual Scientific Meeting of the Society. In this they are no different from the full members. The response to date has been disappointingly poor and has perpetuated the “us and them” mentality. Those few Associates who have attended have enjoyed the meetings, achieved some benefit and have reconciled many differences. I exhort all members of the diving fraternity to join us this year in Port Douglas or next year in Palau. It must be remembered that we all have the same goal, safe diving.

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DIVING FITNESS

Glen Egstrom

Introduction

I am by profession a kineseologist. We study how people perform in a variety of different circumstances. Diving fitness has been discussed from a variety of points of view for many years. Strength, endurance and the specificity of training are cornerstones for fitness and have justifiably been given the lion’s share of the attention. People make remarkably specific adaptations to the imposed demands of the environment and continually seek to gain equilibrium with the stresses applied in training programs. That is a long winded way of saying that just because you are in good physical or medical condition for a particular activity it does not mean that you are in good condition for some other activity. Specific adaptation takes some time. It is not something that happens immediately. The barriers which face the scuba diver, who wishes to perform safely, are biomechanical, physiological, methodological and psychological.

Biomechanical fitness

The Japanese Ama (breath-hold) divers have strength in the functional muscle groups that enable them to force themselves down in the water. They take some incredible kicks and drive themselves down until they become negatively buoyant and then they work their way to the bottom. As young adults, these females work in water depths of 10 m for periods of 6 hours a day in water temperatures similar those off the coast of New Zealand and California. As they become more proficient, they develop the strength to be able to go down to about 30 m on breath hold dives. On the 10 m dives they do one dive about every 2 to 3 minutes, on the 30 m dives they do one dive every 4 to 5 minutes. They do that for 6 hours and they take 30 minutes off for lunch. It is a specific adaptation that most people could not manage. Because they do these dives on a regular basis, they acclimatize themselves and consequently they are able to do it quite comfortably.

The would-be diver faces an interesting challenge. Browning, in the play "Heracles", said that "a man in armour is his armour's slave". The diver has the same basic problem.

A scuba diver can be described as a person about to become involved in heavy exercise who covers the nose with a mask that eliminates nose breathing and then covers the body with a bulky rubber suit which retains body heat, but restricts motion at every joint and causes the body to float significantly. This person then attaches fins to their feet which makes walking difficult and requires a unique kicking style if propulsion through the water is to be achieved. The musculature involved in kicking is likely to be stressed at points in the range of motion where strength may be weak.

This handicapped the person attaches a 20 kg package of weight to the back of the torso with a variety of straps so that the centre of mass of the body is raised 15-20 cm. A host of hoses is attached to the tank on the diver's back. These hoses will provide breathing resistance, water resistance and information relative to the diver's life support status.

After this the prospective diver attaches 7-11 kg of lead to the waist in order to sink the rubber suit and the body under the water. Finally the diver attaches a knife, watch, depth gauge, goody bag, camera or spear gun to the body.

The question we have to ask is "What does this do to performance and what do I have to do in order to make myself fit to be able to handle it?" We put ourselves into exposure suits. Thick neoprene rubber restricts movement. Every joint is going to have to operate against this resistance. The individual who has sufficient strength to be able to wear it like a second skin and has sufficient endurance to be able to pay the energy costs, will not have a problem. Wetsuits have different mechanical problems to drysuits. As a consequence you need specialized training and specialized adaptation to whichever of these suits you are going to use. If you are in a cold water area and you know that you are going to dive in a drysuit it makes absolutely no sense to train in a wetsuit. Train in a drysuit if that is what you are going to dive in. If you train in a wetsuit, use a wetsuit or take another training course in a drysuit before you go out and create a problem for yourself using one.

Individuals who make a switch from non-wetsuit diving to a wetsuit find that they get very tired, very quickly. Many complain about the restriction on their chest, saying "I can't take a deep breath". After they have done it for a while, they either develop some additional strength or learn to tolerate the discomfort. Both biomechanical and physiological issues are associated with strength and endurance which are very important aspects of being fit to dive.

Biomechanical fitness implies that the individual is capable of handling the equipment much as if it were a second skin. This is usually an easy task underwater as the diver becomes nearly neutral following descent. However the topside efforts, under the influence of gravity, may well cause over exertion. The fit of the equipment is also a contributing factor since poorly fitting equipment can cause loss of range of motion, increased drag and increased workload.

We tend to hang things all over our body. A friend of mine has an octopus, a pony bottle, a regulator, gauges, a camera, a snorkel, and hoses hanging everywhere. It is a small wonder that he has turned to photography. All he does now is sit on the bottom and take macro shots of coral heads. But if he had to do anything other than that, he would find that there is a good deal of stress to diving with all that equipment. My dive buddy today, has started to hang things inside his stabilizing jacket, which makes a great deal of sense. It cuts down on the frontal surface area and the drag co-efficient and make it much easier to swim. Usually divers just add another clip and hang something on it.

Physiological fitness

Physiological fitness requires the development of adequate strength and endurance to be able to meet the demands of a particular dive.

As a scuba instructor I have been frequently told by individuals who come into my classes that they are a fitness buffs They run miles every day. Unfortunately the functional muscle groups that are used in the running are not the same as are used swimming. Swimmers move from the hip and use the knee in a way that we do not normally do when we run. So strong muscles for running may do us little or no good when diving.

Strength is best gained at that point in the range of motion of the muscle movement where the highest resistance is met in the activity that is being undertaken. Thus fin swimming requires special preparation in order to be able to handle the resistance developed by the large fins used in scuba.

Endurance is largely cardiovascular in nature and is more generally improved under overload conditions. Medical fitness is very important since a surprising number of would-be divers are not aware of the potential risks associated with going diving without an adequate medical evaluation. The late Dr Jefferson Davis laboured for several years on a consensus guideline on the medical examination of scuba divers with the assistance of nearly 100 doctors drawn from the majority of specialties in medicine. This work[1] is particularly helpful to those not skilled in hyperbaric medicine.

The cheapest insurance in terms of being fit for a dive is to be able to demonstrate that you have adequate fluid balance. Jeff Davis had a really marvellous solution to this. You know when you are adequately hydrated when your urine is clear and copious. Fluid balance has become one of the hot topics in sports medicine over the last four or five years. We have found that performance is seriously degraded under conditions where the person is under-hydrated. The total circulating blood volume goes down. The blood is more viscous. Sludging occurs. It all makes it more difficult to circulate blood through the tissues. We found that we get better performances from people on treadmills when they are well hydrated then when they are dehydrated. As divers we have negative pressure breathing, cold, a little dehydration from alcohol, coffee and respiratory water loss, all impinging on our ability to balance our water budget.

Discussing hydration and dehydration, there is always the question “How much water should I drink?”. One glass of water is not enough. About a litre an hour can move from the stomach into the blood. If you are dumping fluid at a faster rate than a litre an hour, you are not going to keep up. We have to hydrate, not only before dives but between dives, in order to maintain a reasonable degree of fluid balance to be able to handle the exercise conditions that we have when diving.

One of the few things that my students at UCLA ever remember me for is giving them advice about hangovers. If when you finish partying the world is not as it should be, then you should drink three 8 ounce (250 ml) glasses of cold water. Then you go to bed and go to sleep. When you get up during the night you drink another 8 ounce (250 ml)glass of water. You will be remarkably clear-headed in the morning.

The diver has to be able to deal with the stresses that follow the introduction of the body into water under different kinds of workloads with various kinds of conditions. We can recognize the mechanical problems, so we need to have enough strength and endurance to be able to cope with them for two purposes. One is to enjoy at a comfort level our diving. Secondly to be able to deal with the sudden demands for survival. These are two quite different issues.

The comfort level is really easy. Remember that the resistance through the water, goes up as a function of the square of the velocity. If you are steaming along you will increase the resistance at a considerable rate.

Comfort includes being able to use breath control all the time during the dive. It also includes being worry free. A trapped air hose is a real threat to survival. When a diver suddenly becomes aware that his air supply is going to be cut off his pulse rate suddenly climbs to about 170 beats a minute, which is excessive. His equilibrium, his comfort level, has been seriously disrupted. Stress now starts to take a real hold on his performance and he is more likely to make mistakes. As soon as the hose is free, the threat is gone, and as soon as the threat is gone the pulse rate comes down.

Swimming into a current is hard work. If the current is one knot, the majority of people are not going to be able to swim against it more than about 50 to 90 seconds. It pushes our oxygen uptake up to its limit. In our lab studies we find that reasonably well trained people can operate at that level for 40 to 50 seconds. Highly trained athletes might be able to last another 10 to 15 seconds. That means that if you have got to swim hard to catch up with the boat or the Jesus Line you only have a short spurt available. If you miss it and are swept away and keep trying, you may jeopardize yourself because you will not be able to keep going. It becomes important to recognise that if we are going to have to have strength and endurance, we need to exercise the functional muscle groups needed to provide the strength and endurance at an appropriate range of motion. Riding a bicycle does not prepare you well to operate with mask, snorkel and fins in the open sea. If you want to prepare yourself you should be using the functional muscle groups, that you know you are going to use, in the way in which you are going to use them. Being in good shape for running is probably not going to guarantee that you are going to be in good shape for swimming hard against a current.

Methodological fitness

Methodological fitness means using the proper techniques to insure effective and efficient performance. Once the technique has been chosen then it must be over-learned until errors are essentially eliminated. After that, problems which occur can be addressed without having to think about the execution of fundamental skills.

We should always ask ourselves the question “Is this the best way we can do that ?”. This becomes particularly important when dealing with emergency procedures. With a methodology that is relatively simple, straightforward and has been rehearsed a bit, you can expect it to be able to work. If, on the other hand, you are using a methodology that is not over-learned or is not appropriate it may be doomed to failure.

Surf passage is a piece of cake if you do right. It can be life threatening if you do it wrong. Heart rates in the range of 180 have been measured during such events and sadder, and hopefully wiser, divers have been dragged ashore because they lacked the capability to continue under their own power.

Teaching novices to enter 0.9-1.2 m surf we tell them that the only way they are going to survive is by meeting force by force or by avoiding the forces that are coming in. All waves roll when they come ashore. The water moves in a circle, in, down and out. If you dive into the base of a wave, you will be carried under the wave and up on the back side. The individual who stays upright in the face of a wave is going to catch all the white water and all its force in the face. It knocks one over and washes one up the beach. We tell people not to stop in the drop zone. Either go out, by going under, or come back and take care of yourself.

The point is, if you have not totally learned the skills you may not really know what to do. As a consequence you stay there, do nothing and hope for the best. Under those circumstances, a small wave has sufficient force to knock you over and roll you back up the beach.

Knowing what to do and when to do it is extremely important. I mention this because, in many of the things we take for granted, we run into this same problem. How many of you learned buddy breathing using the one regulator passed back and forth? If you had been trained by some of the agencies in recent years, you will not have been taught to share air from a single regulator. But if you were taught, how many of you practised buddy breathing five times or 10 times or 15 times in the basic course?

It takes a lot of practice to acquire a skill like buddy breathing, so that you do not make a lot of mistakes. We studied a beginners' class. When they could buddy breathe satisfactorily kneeling on the bottom we asked them to swim down the pool wall and turn and swim across the pool. As they were going the down the wall an instructor would deprive one of the students of their air. We did it as part of our stress training. At that point, they were out of air. So they went into their air sharing approach. It took 17 to 21 trials before they got right. The commonest mistake was when they made the signal "I'm out of air, I want to share", they would stop swimming and sink to the bottom. Not only did it take 17 to 21 trials before they could do it properly, but we found that if they did not reinforce that skill, every six months, they would go back to sinking. If you have not practised buddy breathing in the last six months you may have a degradation in performance as a result.

How many of you have practised intentionally ditching a weight belt in the last six months? You may say that all one has do is pull on the quick release and the belt goes. In fact, that is not correct.

If you are lucky and the belt slides free after flipping the buckle, that weight belt will slide down your body. Assuming that it has a clear drop path, it may even separate.

A number of you have been given a weight belt that would fit a Sumo wrestler and I have noticed that you just thread the long tongue through the buckle and clip it. There is about a yard of belt sticking out of the side. This is a potential mechanical problem. The buckle pulls away for quick release. As that belt starts to drop the belt no longer withdraws straight out of the buckle. The droop of the belt makes it mechanically thicker, which increases friction against the buckle and it can literally re-close itself. The enlarged loop falls down and hooks on the knife on the outside of the leg. Now instead of being able to take a big kick, the diver is doing little "loop" steps because of the weight belt. I suggest that it is incompatible with good health. It is a mechanical problem and we have to be smart enough, as divers, to avoid that kind of thing.

If you are in in a horizontal position and you open the buckle on you weight belt is it going to fall off? No, a weight belt will not fall off in a horizontal position. The diver has to roll or pull it free. We have done a series of tests of weight belt ditching over the years on manikins and found that if you are more than 30° from vertical, the weight belt will not drop if all you do is open the buckle. It will only fall off if you go into vertical position and can dislodge it. When an individual goes upright the tank comes down and presses firmly against the cleavage of the buttocks. That holds the weight belt in position. You have to flex the trunk and move the tank away or do a positive ditch, pull it away. That is a skill that has to be practised. If you do not learn to do it reflexly, you may not do it at all because you have other kinds of problems beginning to interfere.

Over the years about 70 or 80% of diver fatalities still have the weight belt firmly fixed on the hips when they are recovered. In one incident a man had the weight belt hanging on a crotch strap between his legs. His girlfriend came down trying to disengage the thing, and they both perished. Ditching a weight belt is a skill, like any other thing that you learn. Over-learn the skill, so that you can do it with either hand as a positive ditch. That is not only do you loosen the buckle, but you get the weight belt free and away from the body so that it can drop clear.

People who consistently swim in a head down position are kicking to make up for the fact that they are underweighted. They are using more energy because they have to fight buoyancy on every single kick in order to keep themselves down. On the other hand, those who are leaning forward are over-weighted and are using energy to keep themselves moving through the water to keep themselves up. If you are correctly weighted for the depth you are diving at, you can hold a position parallel to the surface with little or no energy being expended.

Psychological fitness

Psychological fitness in diving is often the most difficult to achieve. The ability to relax and enjoy underwater activity is foreign to many participants in the sport. Each dive, for some, is a victory over adversity and the notion that they cheated death yet another time provides a surge of exhilaration that stimulates them to try again. As the comfort level in diving increases, the diver becomes a waterperson, a comfortable citizen in the world under the sea. Stress is minimal and the fear of the unknown is replaced with anticipation for another great dive.

A changed clientele has created a special of kind of problem for instructors. Instead of having waterpeople to train as divers, we now have a population looking for another recreational pursuit. Many of them are not waterpeople. They are people who come from varied backgrounds. When we take them underwater they are bound to have increased levels of stress if they are normal.

What is it that actually makes us stressed? We gave a group of engineering students a lecture on Boyle's Law, Henry's Law, Charles' Law and how they would operated on a person in a recompression chamber. We told them that when you are compressed it gets hotter and that under pressure, your ears are going to be painful. Then we told half of them how serious it was going to be, what they had to in order to be equalize their ears and that if they did not equalize early and often enough they were likely to rupture their eardrums and that if they did not exhale while ascending they were liable to lung rupture. We put them into a chamber, closed the door and banged the catches tight. What they did not understand was that we were putting them in an altitude chamber, not a hyperbaric chamber. We blew hot air into the chamber. We had a beautiful brass gauge where the needle went right around and redlined at 100 ft of seawater. We were able to sneak a little bit of air in, about half a p.s.i. so that they would feel the pressure on their ears. They dutifully went through all the manoeuvres to get themselves organized. We put them through a series of psychological tests. The performances of the ones who thought that they were in a really bad situation got slightly better the longer they stayed in there and more uncomfortable they became. Those that we did not tell anything to did not have any serious problems in the beginning. But the longer they were in there and the hotter and the more uncomfortable they got, the more their performance went down. What this says is that if we do not deal with stress as a recognised factor, then we are going to have people who may have a distorted view of what is going on.

How do we recognise stress? Things do not look normal. If you look at your buddy and see widely dilated pupils and a steady stream of air coming out of the regulator, it is a clue that your buddy is not happy.

People have fears, usually groundless, that sharks and moray eels are going to bite and that the wild abalone is going to trap fingers, so they will not be able to get off the bottom. All these kinds of things contribute to stress. Stress brings on a syndrome. This syndrome is abnormality, they do not look right. At this stage we have do something to help improve their outlook because if we do not, they are going to go into panic. Panic is blind, unreasoning fear.

People who are going to become divers must have the capacity to be able to exercise self-control even when things start to turn bad. An individual who has the head, shoulders and arms up out of the water has an unusually high level of work. The head weighs about 8 kg (17 pounds), the arms and shoulders are probably another 16-18 kg (35 or 40 pounds). Try treading water with your fins with both arms and shoulders out and see how long you can do that and stay happy. It is about 40-60 seconds if you are in really good shape. Then propulsion slows and the body sinks. By this time you have discarded your regulator because you could not get enough air through it and now you have water in front of your air passages. This creates further excitement, you rear back out of the water and cough and splutter and sink again. After two or three of these immersions you start to lose a lot interest in what is going on. At that point, in many instances, the diver is perfectly willing to give up the whole business. It is not a conscious decision but it is the decision that is made.

Conclusions

We need to recognise the stresses that are associated with the density of water, the work of breathing and moving, temperature changes, gear related issues and a whole series of emotional issues. Motivation to dive is important. If people do not want to dive, it is very difficult to teach them how. If they do not want to solve problems because of their fear of death or whatever, they do not do well in courses of instruction. With that personality type you would be doing everybody a favour by suggesting that they learn how to ride motorcycles or do something where gravity is the only thing which they have to deal with.

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This is an edited transcript of a lecture given by Dr Egstrom when he was the guest speaker at the SPUMS 1991 Annual Scientific Meeting.

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1991 SURVEY OF 27 RECREATIONAL MULTI-DAY DIVING OPERATIONS

Drew Richardson and Karl Shreeves

Abstract

A survey of 7 training organizations, 18 dive resort operations and 9 live-aboard dive operations was done to determine the repetitive and multi-day diving practices actually in existence today. In this study, which represents an estimated 1.6 million dives annually, the typical numbers of dives per day, consecutive days of diving, surface intervals, depth distribution and the safety practices of recreational divers were identified and recorded.

Introduction

Certification statistics kept by International PADI Inc., a recreational scuba training organization, show that recreational diving is on the rise. In 1980, the PADI organization issued 107,404 certifications, in 1985, 260,319 certifications, in 1989, 397,728 certifications and in 1990, 450,883 certifications. As recreational diving has grown more popular, the number of dive resorts and live-aboard dive boats has increased to meet this consumer demand. Both dive resorts and live-aboards offer opportunities for repetitive diving over consecutive days. At the same time, it must be recognized that little test data exists for decompression protocols beyond three or four repetitive dives, or for several consecutive days of diving. While it is intuitively clear from anecdotal reports that recreational repetitive multi-day diving is beginning to push beyond the body of tested decompression practices, it is unclear as to what extent. For example, anecdotal reports of five or more dives daily for six days consecutively on live-aboard boats are common. While there's no proven risk from this type exposure, this type of diving is untested. This study was initiated under the direction of Richard D Vann, Ph.D., Director of Applied Research at the F.G. Hall Laboratory, Duke University Medical Center, to uncover the range of common, intensive recreational multi-day repetitive diving activities.

Methods and materials

The 1991 DEMA (Diving Equipment Manufacturers Association) Show in Las Vegas, Nevada, offered an ideal opportunity to conduct the survey. The annual DEMA show brings together, among other dive industry members, global representatives of dive resorts and live-aboard dive boats. Using a confidential survey form (see Appendix), a personal interview was conducted with representatives of resorts and live-aboard operations at the 1991 DEMA Show. The interviewer asked probing questions on procedures and sought to capture reports on standard operations and decompression procedures. Dr. Vann assisted this questioning by reviewing the survey form prior to the survey.

Eighteen dive resorts, nine live-aboard dive boats and seven training organizations were interviewed. It is significant to note that some operations operate more than one live-aboard boat or resort, so the number of such boats and resorts represented by this survey exceeds 27. An effort was made to give the survey a worldwide distribution, though the Caribbean, which has a large concentration of such operations, has more weight.

A guarantee of confidentiality was given to interviewees to encourage accurate reporting free of competitive concerns or possible complications with their respective training organizations. All interviewees worked first-hand with diving operations. Second-hand reports of diving practices were excluded.

Many interviewees answered questions with ranges rather than specific numbers; in many cases, it was necessary to use a single number from such ranges to derive data. In these instances, the lowest number in the range was used. An example of this the estimation of 1.6 million dives per year being represented by this survey. This was as the total of all dives at all operations as derived in this example:

For an operation reporting 6,000-7,000 divers per year, 7 to 10 days diving per diver per stay and 3 to 6 dives per day:

6,000 X 7 X 3 = 126,000 dives per year.

Specific comments regarding the data accompany some of the following tables.

The survey sought to compare the number of days

TABLE 1

DISTRIBUTION OF OPERATIONS

Location	Resorts	Live-aboards
Worldwide multiple operations	2	2
Australia		1
Bahamas	2	2
Bonaire	1	
Cayman	4	
Cozumel	2	
Fiji	1	
Florida	1	
Hawaii	1	
Honduras	1	
Micronesia	2	1
Red Sea		1
St. Lucia		1

TABLE 2

APPROXIMATE NUMBER OF DIVERS PER YEAR

	Resorts	Live-aboards
1,000 or less	1	4
1,001 - 5,000	9	2
5,001 - 10,000	2	3
10,001 - 15,000	2	
15,001 - 20,000	1	
20,001 - 25,000		
25,001+	1	
No answer	2	

spent at a resort or on a live-aboard with the number of days on which dives were actually made. The ratios of "number of days at operation"/"number of actual dives days" are shown in Table 3.

The averages in tables 3 and 4 came out of the data. "Of operations surveyed" is the average number of days reported by the operations. "Of diver per season" is the average of all the divers at all the operations staying the number of days reported by each operation. In both cases, the lowest numbers were used when ranges were given.

The numbers in table 5, showing the number of dives per day, are based on the lowest numbers reported by each operation. Five (55.5%) live-aboards reported dives-per-day routinely exceeding 5.

Table 6 gives the dive depths typically used at the various operations. Only 5 live-aboards and 12 resorts operations could estimate general dive depth distribution. This distribution is adjusted based on number of dives (based on lowest in ranges) per season at each reporting operation.

Table 7 gives the typical surface intervals. In general, resorts were able to give more accurate estimates of surface intervals. Live-aboards reported greater variation and tended to be more vague.

Reports on DCS from both resorts and live-aboards

TABLE 3

DAYS SPENT AT OPERATION/ACTUAL DAYS DIVING

Ratio days at operation to days of diving	Resorts	Live-aboards	Both Groups
3/2	1 (5.5%)	0	1 (3.7%)
3/3	1 (5.5%)	0	1 (3.7%)
4/3	1 (5.5%)	1 (11%)	2 (7.4%)
4/4	2 (11%)	0	2 (7.4%)
5/4	2 (11%)	0	2 (7.4%)
6/5	0	1 (11%)	1 (3.7%)
7/5	2 (11%)	3 (33%)	5 (18.5%)
7/6	5 (28%)	3 (33%)	8 (29.6%)
7/7	0	1 (11%)	1 (3.7%)
8/6	1 (5.5%)	0	3 (3.7%)
Insufficient information	3 (17%)	0	3 (11%)

TABLE 4

AVERAGES OF DAYS AND DIVES AT OPERATIONS

Average days spent with operation

	Resorts	Live-aboards	Both Groups
Reported by operations	5.66 days	6.55 days	6.00 days
Diver per season	6.39 days	6.64 days	6.44 days

Average days diving

	Resorts	Live-aboards	Both Groups
Reported by operations	4.66 days	5.33 days	4.91 days
Diver per season	4.9 days	5.57 days	5.00 days

TABLE 5

NUMBER OF DIVES PER DAY

Number of dives/day	Resorts	Live-aboards	Both groups
2 or less	13 (72.2%)	1 (11%)	14 (52%)
3	5 (27.8%)	1 (11%)	6 (22%)
4	0	5 (55.5%)	5 (19%)
5	0	2 (22.5%)	2 (7%)
Dives per day average			
Of operations	2.24	3.83	2.77
Of diver per season (16 resorts reporting)	1.95	3.42	2.23

TABLE 6

TYPICAL DIVE DEPTH DISTRIBUTION

Depth range in feet	Resorts	% of dives Live-aboards	Both Groups
0-30	18%	6.0%	16.0%
31-60	31%	54.6%	35.0%
61-90	40%	24.0%	37.4%
91-130	10%	14.8%	11.0%
131+	1%	0.6%	0.6

TABLE 7

TYPICAL SURFACE INTERVAL DURATION AT 18 RESORTS AND 7 LIVE-ABOARDS

Surface Interval	Resorts	Live-aboards	Both Groups
0 to 60 minutes	12 (67%)	2 (29%)	14 (56%)
61 to 120 minutes	2 (11%)	1 (14%)	3 (12%)
121 to 180 minutes	4 (22%)	3 (43%)	7 (28%)
181 to 240 minutes	0	0	0
241 to 300 minutes	0	1 (14%)	1 (4%)

tended to be vague and guarded. No relationship between days dived or number of dives per day and DCS cases reported was found.

The following "worst case' DCS incident rates were derived based on "less than per 1 year" = 1, and using the fewest estimated dives per year.

Resorts:	1 case in 63,882 dives (0.0016%)
Live-aboards:	1 case in 34,300 dives (0.0029%)
Both groups	1 case in 49,996 dives (0.002%)

Table 9 shows computer usage based on averages of percentage estimations by operations and their divers-per-season.

Mutli-level is defined as permitting profiles that extend bottom time beyond the No- Decompression Limit (NDL) of the deepest depth by crediting for ascent to a shallower depth. All live-aboards said they permit multi-level diving. One resort said it permits neither multi-level diving nor computer use. Other resorts that do not permit multi-level diving said they permit divers to use computers, but only as time/depth gauges.

The incidence of decompression diving and the safety

TABLE 8

DECOMPRESSION SICKNESS REPORTED

Cases per years	Resorts	Live-aboards	Both Groups
less than 1	15 (83%)	5 (56%)	20 (74%)
1	1 (6%)	1 (11%)	2 (7.4%)
2	2 (11%)	2 (22%)	4 (14.8%)
3	0	0	0
4	0	0	0
5	0	1 (11%)	1 (3.8%)

TABLE 9

PERCENT OF DIVERS USING COMPUTERS

Resorts	23%
Liveaboards	58%
Both Groups	29%

recommendations of skipping a day's diving (multi-day skip) and safety stops in the various operations is shown in Table 11. Four resort operations reported 3 or fewer days of continuous diving. Multi-day skip was considered "standard" if an operation requires it, or if most divers at an operation routinely take a day off during their stay. Every operation that did not require a safety stop said that it strongly recommends safety stops.

Training Organizations

Seven training organizations, including PADI, were surveyed as to whether their training standards affect multi-day, repetitive diving. There was virtually no difference in any of the organizations. They all allowed a maximum of two training dives per day at entry level. None had restrictions on non-training dives after certification. All advise conservatism when making multiple repetitive dives over multiple days,but no specific guidelines were given.

PADI's Standards, as presented in the PADI Instruc-

TABLE 10

AVERAGE REPORTED PERCENTS OF COMPUTER-USING DIVERS

	Resorts	Live-aboards	Both Groups
In operations permitting multi-level diving.	39.5%	55%	46.8%
Range	5%-90%	5%-95%	5%-95%
In operations not permitting multi-level diving.	19.1%	NA	19.1%
Range	0%-50%	NA	0%-50%

TABLE 11

STANDARD OPERATIONAL PRACTICES

		Resorts	Live-aboards	Both Groups
Multiday skip	Yes	3 (17%)	2 (22%)	5 (18.5%)
Multiday skip	No	11 (61%)	7 (78%)	18 (66.7%)
3 or less days of continuous diving		4 (22%)		4 (14.8%)
Decomp diving	Yes	2 (11%)	3 (33.3%)	5 (18.5%)
Decomp diving	No	16 (89%)	6 (66.7%)	22 (81.5%)
Safety stop required	Yes	12 (66.7%)	7 (78%)	19 (70%)
Safety stop not required	No	6 (33.3%)	2 (22%)	8 (30%)

tor Manual[1], give an example of how training organizations address multi-day, repetitive diving:

"No more than two open-water scuba training dives are to be conducted in a single day for any individual student (the only exception is the Advanced Open Water Diver course, which allows a night dive to be conducted following two daylight dives)."

The PADI Open Water Manual[2] advises:

"Since little is presently known about the physiological effects of multiple dives over multiple days, you are wise to make fewer dives and limit your exposure toward the end of a multi-day dive series."

In The Undersea Journal[3], PADI's instructor journal, PADI members were advised:

"DAN suggests that divers engage in no more than three or four consecutive multi-dive days. For example, on extended trips during which the diver is making more than two divers per day, he should refrain from diving every third or fourth day."

Discussion

From a mathematical point of view, the number of surveys in this project makes a high statistical confidence level difficult. Nonetheless, this does not mean the information is inaccurate and the data strongly suggest that some diving practices are prevalent. If these practices exist to a greater or lesser extent than found in this survey, this survey at least reveals a need for closer examination.

EXTENT OF MULTI-DAY DIVING

There's no question that multi-day diving repetitive diving is wide-spread. The survey showed that the "typical" diver dives about five days during a six-and-a-half day stay at a resort or on a live-aboard. Apparently, taking a day off during a multi-day dive series (multi-day skip), while not uncommon, is not the prevalent practice at resorts or live-aboards. One resort operation that caters for approx. 12,000 divers annually at three resorts said that the multi-day skip had become less common since the release of the new flying-after-diving recommendations, which make it difficult to dive on the last day of the trip.

EXTENT OF REPETITIVE DIVING

While the number of days dived were similar for resorts and live-aboards, there's a tendency to make more dives per day on a live-aboard than when at a resort. The "typical" diver makes 1.95 dives daily at a resort, compared to 3.38 on a live-aboard (about 73% more dives per day). Live-aboard reports reaching 5-6 dives daily were not uncommon, with as high as 10 dives in a day being reported.

SURFACE INTERVALS

Interestingly, resorts showed shorter surface intervals. Apparently, the common resort two-tank morning or afternoon schedule keeps surface intervals at dive resorts short, while live-aboards, which do not have tight schedules to keep, can afford a more leisurely pace between dives. This is supposition supported by the reports. Resorts gave fairly accurate specific intervals, which is consistent with running a regular schedule, whereas live-aboards tended to be more vague and cited little regularity to surface intervals.

TYPICAL PROFILE

It was hoped that a "typical day's dive profile" would be found by this survey. Instead, it was found that there's no such thing across the board. Live-aboard boats had difficulty citing "typical" profiles, so it's impossible to extrapolate a "typical" live-aboard profile, other than diving deep in the mornings and shallower as the day progresses. Several resorts gave their daily profiles, making a rough "typical" resort profile:

First dive: 60 to 100 feet deep for 5 minutes less than the NDL. Surface interval: 30 min to 1 hour. Second dive: 60 feet or shallower for 35 to 45 minutes.

COMPUTER USE

There is a significant number of divers using dive computers, and most operations said the number is growing. The least computer use was found among resorts that do not allow multi-level profiles and among resorts and live-aboards in predominantly shallow (majority of diving above 30 feet) regions. In the latter instance, it can be speculated that because of almost unlimited dive time permitted by tables in the shallows, divers do not perceive a need for the additional time afforded by a computer.

The greatest dive computer use was reported among live-aboards. It can be speculated that the lack of tight schedules permits a live-aboard to grant divers nearly as much dive time as they want, making a dive computer especially useful. One live-aboard that specializes in deep water wrecks reported that without a dive computer, a diver misses most of the dives. Not surprisingly, this operation reported that 95%+ of its customers use computers.

DECOMPRESSION DIVING

Although decompression diving is generally considered beyond the parameters of recreational diving, five operations reported that decompression diving was permitted. This is a surprisingly large portion of the group (18.5%) and could be a fluke caused by the small size of the survey, or, on the other hand, could indicate that decompression diving among recreational divers is more common than previously suspected.

All but one of the operations that permit decompression diving said they have strict guidelines for decompression dive supervision and minimum experience and/or training levels for participants.

RESTRICTIONS

The survey found that while virtually all resorts enforce guidelines for diving, the degree of restriction varies considerably. Some resorts, in particular, specify the exact dive profile, including depths, bottom times and surface intervals. Other operations stipulate broader rules, such as "Do not exceed the no decompression limits" and other safe diving practices, leaving the diver to use his table/computer to the best advantage within the guidelines.

No operation reported widespread difficulties in getting divers to stay within the limits they set. Operations with the least restrictions tended to show more dives per day and more computer use, suggesting that many divers will take advantage of more dive time if it's available.

No relationship was found between DCS cases reported and the degree of diving restrictions reported by operations. For example, the operation reporting the highest DCS incidence (5 cases per year average) had a restriction of only two permitted per day, and reported that multi-day skip is standard procedure. Another operation that permits decompression dives, dives below 130 feet, and typically offers five dives a day for six days continuously reported only two cases of DCS in seven years.

WHAT WAS SAID

All operations were asked if they specified particular tables, computers or had any other special procedures or considerations that involve dive profiles and DCS avoidance.

The DSAT Recreational Dive Planner and the USN tables were mentioned several times, and Bühlmann tables mentioned once, though no one "required" the use of any particular table, except as in training as specified by training organization standards. Some resorts avoid the issue by dictating maximum dive depths and times. No make or model computer was named in any context, neither as particularly favoured nor as being unacceptable.

Virtually every operation requires or highly recommends safety stops. No other stipulation regarding ascents was made, though it can be inferred that all operations expect divers to stay within the ascent rates specified by their tables or computers.

There was no mention of nitrox, oxygen decompression or other mixed gases associated with professional/ technical diving.

Conclusion

DAN diving accident statistics have shown that more DCS accidents occur following multi-day diving, but this may simply reflect the growing number of divers making multi-day repetitive dives rather than any particular risk of DCS caused by current recreational multi-day diving procedures. Without information on the numbers of dives made single-day versus multi-day, it's impossible to ascertain statistically what role, if any, multi-day repetitive diving plays in DCS risk.

The survey found that multi-day repetitive diving is widespread and common among recreational divers, and that much of it involves more than three dives a day, with five and six dives daily not uncommon. Despite possible concerns raised by accident reports, the survey found no particular evidence of unusual risk from multi-day, repetitive diving as it is currently practiced within the recreational community. This survey found a somewhat higher DCS-per-dive rate for live-aboards than resorts, but a) the small survey size plus using "less-than-1-case-per-year = 1-case-per-year" in determining DCS figures makes it hard to have high confidence in their exactness, and b) even the higher rate indicates less than 3 cases in 100,000 dives.

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TABLES OR COMPUTERS; HOW BEST TO CONTROL DECOMPRESSION

Glen Egstrom

Decompression

Every dive is a decompression dive involving on-gassing and off-gassing from the blood and tissues. There is no such thing as a no-decompression, or more properly a no- stop, dive. We use that term to describe dives from which direct return to the surface is usually safe. The rate at which we on- and off-gas the tissues is a function of the pressure gradient, solubility and diffusion characteristics of the gases and of the blood flow in various tissues. Multi-day multi-level diving may result in residual nitrogen levels that accumulate over a period of days which may not be reflected in the tables or in diving computers which are not kept operational for the duration of multi-day diving excursions.

All tables and dive computers are based upon assumptions. The assumptions may reflect interpretations of research findings, attitudes of the designer, consistencies of human behaviour, environmental constants, consistent rates of change in pressure, and other factors which are not readily quantifiable. It should be clearly understood that the assumptions are largely unavoidable since the state of the art is still under development. Tables and computers are different because the people behind them have used different assumptions, different techniques, different kinds of modelling formula and unsurprisingly, they come up with different answers to basically the same problem. The purpose of table and dive computer technology is to provide criteria and monitoring capability that will enable a diver to plan, and execute, a reasonably safe dive profile, one with a low probability of a decompression accident. They are tools that can help us minimize risks. We must accept their limitations when we plan and execute our dives and to do that the diver must develop the understanding and skill to be able to use them effectively. The old saying that only a poor carpenter blames his tools applies to divers.

The current emphasis on safe decompression procedures has led to considerable confusion. Much of the confusion appears to be related to a fundamental misunderstanding. Many people buy a decompression table or dive computer with the belief that it is going to protect them from decompression sickness. Allegations that a particular table or dive computer “bent” someone should be viewed with extreme caution since tables as well as dive computers are simply tools used to reduce the risks associated with decompression in diving. There is not and never has been a set of tables, or a dive computer, that can eliminate 100% of the risk of a decompression accident 100% of the time. One of the reasons for that is pretty obvious, we are all different physiologically. There is wide inter- and intra-individual variability in the response to a given diving profile. At best, we take a calculated risk each and every time we dive. The best we can hope for is that the table or dive computer we are using on a given dive profile will be compatible with our individual response and result in a problem free ascent.

Divers, decompression tables and computers

There are many divers who still have not got the foggiest clue as to what decompression really means. They simply want to be told what to do and when. Probably the most common decompression routine is where the divemaster says 24 m for 30 minutes. One comes up at the end of the dive, sits out for 45 minutes to an hour and then is told to go back to 18 m for 40 minutes. Everyone dutifully goes about their business. Fifteen to 20% ignore the instructor completely. They go as deep as they want and stay as long they want and, if they come back up to the surface without any difficulty, they write down depths and times using the “Woolworth Effect” (everything finishes in 5s and 10s).

The current situation with regard to tables and dive computers reminds me of a remark by Poul Anderson, many years ago, when he observed, “I have never encountered a problem, however complicated which when viewed in the proper perspective did not become more complicated”.

Individuals should know and appreciate their own limitations in relation to each dive. Neither the table nor the dive computer has a clue regarding ones physiological and mental state. To reduce decompression sickness risk in divers we have to look at other things as well as depth and time. A few of these are age, obesity, physical exertion, hangovers, state of health, physical condition, post-dive exercise and dehydration. We dump an awful lot of water while diving. Immersion decreases central blood volume and negative pressure breathing also inhibits antidiuretic hormone. Dry gas is saturated during respiration. You are exercising, you sweat underwater at a high rate. All these mechanisms take water out of the blood and put it in other places, including the open sea. A diver working for an hour at 45 m will lose about a litre and a half from his circulating blood volume. One does not have to go that deep to be losing roughly equivalent to the amount of fluid that an athlete loses when running a marathon. You can lose about a litre to a litre and a half an hour, and you should be replacing that fluid or you are going to end up in a dehydrated state. This can be cumulative over a number of days. It is also important to recognize that individual susceptibility to decompression illness can change during the dive and between dives on the same day as well as between days.

Regular exposure to increased pressure appears to reduce individual susceptibility to decompression sickness. Thissuggests that a progressive increase in exposure to greater depths is a good idea and that deep dives following long periods of inactivity are a bad idea.

The past

When I started diving there was only way to do the job. You went in, followed the instructions, did the dive the way you were supposed to and a certain number of people got hurt and that was of the way the ball bounced. In fact, when we dive we are still taking a calculated risk each and every time we put our heads under the water.

My first depth gauge was a capillary depth gauge. It was amazingly simple and extremely accurate in shallow water. But it gets a little less accurate as one goes deeper and finally the lines get so close together that one cannot be sure of the exact depth.

Later bottom timers and depth gauges that are accurate over a wider range were produced because it is important to monitor depth and time. We really have not come very far since then. We now pay $US 400 to $US 600 for devices that are very good time and depth recorders. But they also do calculations that may, or may not, be in our best interest 100% of the time. A computer does not do any more than we have been able to do from the time since we first had waterproof watches and some kind of depth gauge.

Divers get into the water and look down. The water is clear and everything is wonderful. Someone in the group sees something in the distance We wander down. As we go down we notice that light does not penetrate as well as it did. That does not stop us and probably never will. At around 36 m we find something that is truly wonderful. We now have a focus of interest. Unfortunately humans, when we start to narrow our focus, tend to forget about peripheral things like time and depth. We lose interest in having to leave this depth before doing all the things we want to do. Finally someone probably notices that we have been down quite a while, looks at the depth gauge and at the watch. If they can remember what time they left the surface, they may have a clue as to how long they have been on the bottom. Then we start to round up the troops and go up to towards the surface.

Even in the good old days, if we knew that we had over stayed our welcome in the deep we took it upon ourselves to do some kind of hang off somewhere in the water column. Most of us were trained that one must hold the depth gauge level with the centre of the chest and it must read precisely 3 m (10 ft). This proved difficult, because occasionally swells came through and one went from 3 to 6 m (10 to 20) ft very rapidly.

Tables

We had the much maligned US Navy (USN) decompression tables of 1958, where 18 m for 60 minutes is a no-stop dive and at 36 m 15 minutes is a no-stop dive. These tables have the largest database and smallest incidence of accidents of probably anything we have with a comparable number of exposures. I get a little annoyed when people say the USN tables are bad. There are some areas in the USN tables that we know are not what they should be and it took many, many years find that out. Thousands of dives have been done safely on these tables, primarily because very few people, including the old USN Chiefs that run USN diving, ever operated the tables as they appear on the page. Most of the dives were done at shallower depths. They were not done as square dives, they were done as some kind of variation of a square dive. The tables accepted a particular incidence of decompression sickness. Rumour has that it one time it started off with a model of 5%. As the tables were refined it came down. The last time I heard it was 0.6%, less than one in a hundred. One in a hundred is still a pretty high incidence when one thinks of the kind of damage that can be done. But the bottom line is that these tables are still widely used today. Many people reject some of the other tables because they do not really understand what advantages they would get from them.

There are a number of tables available that are literally the USN tables, rearranged in layout and how to read them. The numbers and the assumptions underlying these tables are the same. Some tables were rearranged because the producers thought that divers were not bright enough to learn how to use the tables. So they gave them something to put a finger on and run it around three or four places to give better accuracy and so better protection. Unfortunately the protection available does not change with the format.

The recreational divers now using the USN tables are not young, healthy, male, athletic individuals who are under military discipline. So diving organisations reduced times. There are tables with shorter no-stop times, 50 minutes at 18 m instead of 60. There are minor modifications in terms of how these tables predict on- and off-gassing. This is an interesting approach because logic says if we cut the times down we are making these tables safer. But, in fact, making the times shorter does not eliminate the possibility nor the probability of decompression sickness. There are too many other variables.

The DCIEM tables are very popular because they are very conservative. They have a database and an experimental background. It is interesting that when doing the Doppler studies there were bubbles on about 70% of the dives to the limits of depth and time. They were only grade one or grade two bubbles and sometimes a few grade three bubbles. The DCIEM team were not really concerned unless there were grade three bubbles or higher.

Then there is the Recreational Dive Planner or the PADI Wheel. The PADI wheel is accumulating a good database. It has received a great deal of marketing acceptance. It is probably as good as anything that is about. It uses the 60 minute tissue to control the repetitive interval because that fits better with typical recreational dives than the 120 minute tissue used by the USN tables. It is based on certain assumptions that differ from the other tables. The tables are being tested and a database is being accumulated. However, it is not going to be a bends free table as there is no such thing. As long as we understand these facts and make the decision that we want to use it and agree that we will take the calculated risk that this particular device puts on us, then everything is fine.

If people are bubbling on the most conservative dive tables that we currently have, we have a problem. After your dive today probably more than 60% of you would have Doppler detectable bubbles, for one reason or another. If you get on a bicycle ergometer and pedal up to a maximum VO2 level wearing a Doppler, you start throwing some bubbles at 1 ATA whether you had been diving or not ! Bubbling may not be the best criteria that we have for safety. But it bothered me as, to me, bubbles have been the problem. Even though the bubbles are on the venous side, and the lung is a wonderful filter, we now know that bubbles can pass through a patent foramen ovale or other shunts to the arterial side. So any bubbles seem to be something that we should be concerned about as there are circumstances under which the lung does not filter as well as it does at other times. We do not really know much about that and none of that is built into the tables.

All tables have the same basic problem. They are concerned with depth and time and certain figments of the imagination. The figments are the assumptions that tissues fall into compartments that have different half times. There are a number of things that interfere with those assumptions, but using half times is still the way that tables are derived and we have data that says that they work really quite well. There have been thousands, perhaps hundreds of thousands , perhaps millions, of dives on virtually all the tables and we have a relatively low incidence of decompression sickness. Perhaps not as low as it should be but it still relatively low.

Shrinking bottom times

The USN tables no-stop time of 25 minutes at 30 m was accepted for a long time. Then NAUI, PADI, Huggins and the BS-AC reduced the no-stop limit by 5 minutes, in order to make it more compatible with the recreational population. The Suunto dive computer cut it to 18 minutes, the Germans came down to 17 minutes, the DCIEM tables came down to 15 minutes, the MicroBrain and MicroBrain Pro Plus went to 12 and 11 minutes respectively. Incidentally, the algorithms in these two are done by the same man.

There is the new terminology of risk assessment. It perhaps is not new in epidemiology, but for diving it is new. What would you have as bottom time at 30 m if you wanted to have a maximum risk likelihood of 1% ? The current wisdom says that is going to be 8 minutes. Now there is a considerable difference between diving 8 minutes at 30 m (to get that kind of protection, but notice it is not perfect, and spending 25 minutes at that same place with a risk that is still less than 1%, statistically 0.6%. I just want to know who is right. I want someone to tell me what I should do so that I can get maximum protection.

Each dive computer that comes onto the market gives less bottom time than the one before it. I think the logic behind it is "I have an algorithm that is safer than their algorithm, how can I be criticised?". So each one in turn came out with less. There is a serious problem. If my understanding of human nature is correct, no one wants to buy a computer that only gives 9 minutes when his peers are buying ones that give 18 or 20 minutes. That would be like saying I am not as good or not as fit as they are. So divers go out shopping for the set of tables or dive computer that is going to give the most time. Divers want to be able to stay down as long as possible.

The old SOS decompression meter, rather rudely called the "bendomatic", when tested against a set of tables would often allow the same no-stop dive on every dive of a repetitive series. The tables however would start stacking up decompression time so at the end of the four dives the SOS meter would be about a half hour of decompression time short. Some got and some did not get decompression sickness.

Dive computers

The next step was when a group of people put together an electronic device. We entered the computer age. Orca Industries, in conjunction with Carl Huggins, put together some algorithms and some computer technology. The Edge is a very fine watch and depth gauge with some assumptions in terms of what depth and time mean relative to tissue compartments. A dive computer has a pressure transducer, an internal clock, a microprocessor unit, a read only memory, access memory, power supply and some way to display the results. Within this basic construct we put the infinitely variable human mind to work. We all have ideas about how and what kind of information should be displayed.

Once an individual was found to be wearing a Edge with the five holes that let water get to the pressure transducer firmly against his forearm. When asked why he said that it was the physiological monitoring area and he assumed that it was monitoring his physiology. He would occasionally make sure that it was in position so that the monitor would work. When it was suggested that for it work properly he should have put the openings away from the skin he was outraged because he thought that for around $695, he was getting something that was monitoring his decompression status. He was angry when he found out that all it is monitoring is the Edge's decompression status. If you have the same characteristics as the program inside the Edge you will be in good shape. If not you have a level of risk associated with decompression that is a function of how different you are to what is going on inside the machine.

The American Academy of Underwater Sciences (AAUS) recently brought together 50 people from all over the world, representing medicine, physiology, physics, engineering, highly experienced divers and instructional agencies. At Catalina Island we went through a lot of the concerns associated with the question of "Do we use computers or do we use tables?".

The basic problem is that using five computers, as I did, to track the same series of dives it became obvious that there are variations that ranged from owing decompression to having hours of remaining dive time. This is really unfortunate. The reason is that the algorithms developed for the different dive computers are different. Also each meter, not only had a personality that differed from its counterparts in the industry, but in many instances they have little idiosyncrasies that provide subtle differences between instruments, such as variations in pressure transducer sensitivity.

Part of the difference is the way they treat multi-level dives. We want to keep track of on-and off-gassing as we progressively move towards the surface during our dives. This is generally the way that recreational dives are done and there is a lot of heartburn associated with getting a square dive calculated risk when making a multi-level dive which should be getting safer.

Because of the differences between computers each diver relying on a dive computer to plan dives and indicate or determine decompression status must have his own unit. AAUS had to make that rule when setting guidelines for scientific divers because a number of folks involved thought that one per buddy pair, like a dive watch, was entirely adequate. But if you have on any given dive two dive computers, you must follow the more conservative dive computer. My dive buddy today, I think would have been a little more than reluctant to dive with me had he known that on virtually every first dive this week, on one of my computers I went into decompression. On the other one I had not. That is part of the risk that I take as an individual.

Once a dive computer is in use it must not be switched off until it has indicated that complete out-gassing has occurred or 18 hours has elapsed, whichever comes first. If one leaves an Edge on all week usually by the second or third day it is saying that you still have some nitrogen left over from yesterday and the pixels start building along the slow tissue compartment side of its face. That is probably reflecting real life.

The notion that we can dive for infinitely long periods in shallow water for multiple days is now recognised as more hazardous than previously thought. We are now more concerned about the potential damage of long multi-day and multi-level diving than we have ever been in the past. The dive computer does enable us to dive multi-level because it says you pay for what you are using at any given time. When using an Edge watch the pixels fill in. Notice that the fast tissues go in really quickly. But when you come up a bit the pixels empty almost instantaneously. The ones to be concerned about are those of the slow tissues that tell you how much nitrogen you are retaining.

Ascent rate equals the rate of change of the pressure gradient for decompression purposes. Rapid gradient changes have been identified as a potential trouble-maker in the case of decompression problems. Years ago Campbell showed that divers come up much faster than they USN tables require. A group 20 or so sport divers were taken to the bottom where they were at at 18 m (60 ft). They were given some nonsense arithmetic to do. The observers were ostensibly studying the effects of shallow water narcosis. They were, however, studying ascent rates. They had a signalling device to the surface. When the person left bottom, the signal started a stop watch, which was stopped when the person broke the surface. The time was recorded. The divers were asked "Did you come up at your normal ascent rate?" The answer was almost always "Yes". "How fast did you come up?" Those who could answer this usually said "I came up at no faster than 60 ft per minute with my small bubbles". However when we analysed the data, the average ascent rate for the group was about 51 m per minute.

At this time there is confusion regarding the safe rate of ascent. Tables and dive computers are based upon rates of ascent ranging from 9-18 m per minute. The Edge has three different ascent rates depending upon where you are in the water column. The majority opinion is that ascending at 12 m per minute is better than ascending at 18 m (60 ft) per minute. Slower ascent rates are probably less likely to produce problems for divers.So the AAUS has said that its people will not ascend faster than 12 m per minute in the last 18 m of the water column.

Most people ascend much more rapidly than they think they do because none of us have a really good way of being able to monitor ascent rates. Some of the dive computers today have little lights or messages that will come on and if you are watching, the computer will tell you when you are exceeding the ascent rate. Some of them even have audible alarms.

A couple of computers, that are no longer manufactured, simply shut down if you ascended too fast. It would not give any more information. That was supposed to be a clue that you should not dive again until the computer turned itself on some time later. An ingenious idea but it left the diver without advice during the over-rapid ascent.

Taking a stop between 3 and 9 m for 3 to 5 minutes, whenever practicable, is really cheap insurance. The advantages of taking safety stops at depths of 5-6 m rather than 3 m include better control of depth and position and possibly more stable off-gassing. This advice is tailored primarily for those people using dive computers.

The majority of the computers will let you go back to 30 or 45 m just about any time you want to. This is based on the assumption that if the controlling tissue is a fast tissue, it has off gassed. There was an Edge Club, which was going to do a 39 m dive until the pixels filled the no-stop area then come up and sit until those tissues cleared, then back down to 39 m and repeat the process all afternoon. They had some problems.

One of the first rules one learns about repetitive diving is "Always make your deep dive first and every dive following that in a 24 hour period, shallower". That is pretty good advice. Even if the mathematics in the dive computer says that you can make these deep repetitive dives, humans really cannot. You have to be smart enough not to make that kind of a mistake.

One day, perhaps, we will have a dive computer that may be able to factor in a few of the other variables. When you are facing into a current, your work rate is much higher than when you are making a nice easy drift. This sort of thing has not been factored into any of the computers or any of the tables that we currently have. The closest thing is a statement in USN tables that said, if the dive is cold or arduous, you must take that into consideration by going to the next gradient on the time/depth scale.

Deep diving

We have a deep dive mania developing in the United States. People want to go deeper, they want to stay longer and they do not want to have to pay the price in decompression time They have gone into this "recognising that we can use air a lot deeper than we thought". A man claims to have done a 452 ft dive on air. I think the only people to witness that dive was the man and his girl friend. That dive is clearly beyond the bounds of what we would consider reasonable. However there are some dive computers that are designed to accommodate this quest for depth.

We also have computer generated designer tables. Cave divers produce one off tables for a particular penetration using a PC fed with the depth profile and the gas mix (which may be or may not have been obtained by gas analysis). These tables are used completely untested. They also do not take into consideration any of the other variables.

Conclusions

One's risk of bends is unpredictable on any given day or any given dive. The best thing you can do is dive conservatively. Diving conservatively is not going to prevent decompression sickness. We have to understand that it is one of the calculated risks we take as a diver. If we do get decompression sickness, we should not run around screaming for someone's head to roll, because the bottom line is that each individual who uses a table or dive computer does, in fact, elect an informed consent to all of the risks in diving. That requires education. In most instances the manuals that come with tables or computers discuss the nature of that risk and in doing so put the burden squarely on the diver. If you do not know what you are doing perhaps you ought not to be doing it.

The limits of the tables and the dive computers are arbitrary as are the designations of tissue half-times and other concepts used in modelling the decompression schedules. These devices provide guidelines. Those divers who press the devices to their limits are working in the vicinity of the cutting edge and should not be surprised if they are injured.

This is an edited transcript of a lecture given by Dr Egstrom when he was the guest speaker at the SPUMS 1991 Annual Scientific Meeting.

Glen H. Egstrom, Ph.D., is Professor Emeritus of Kineseology at the University of California, Los Angeles (UCLA).

Dr Egstrom's address is 3440 Centinela Avenue, Los Angeles, California 90066, U.S.A.

ARTICLES OF INTEREST REPRINTED FROM OTHER JOURNALS

ALTITUDE EXCURSIONS AND THE 24 HOUR RULE

Bruce Wienke and Dennis Graver

Abstract

A recent UHMS Workshop on high altitude diving and flying-after-diving recommended a 24 hour surface interval between normal diving and flying, and a 48 hour interval between decompression diving and flying. Consistent with these recommendations, a set of conservative high altitude diving protocols and flying-after-diving procedures can be extracted from the US Navy Tables, by using a 635 minute tissue compartment (after Bühlmann) to control flying-after-diving. Within the group structure of the US Navy Tables, a set of arrival and limiting groups for altitude excursions can be tabulated. Introduction of the 635 minute compartment multiplies times in the US Navy Standard Interval Table by a factor of 5.4. Protocols consistent with the 24 hour rule are described. Restrictions on flying-after-diving, penalty groups upon arrival at altitude, and minimal groups permissible for ascent are summarized. Concerns about Haldane extrapolations at altitude are included.

Introduction

Present diving schedules are based to a large extent on the Haldane model,[1-7] constraining activities so that critical tensions, M, or ratios R = M/P, for P ambient pressure, are not compromised. An approach to altitude diving that is more conservative than even the tested schemes of Buhlmann[2], Bell and Borgwardt,[4] holds the ratios, R, constant at altitude, forcing altitude exposures to be similar to sea level exposures.[7-11] Such similarity will force M to decrease expontentially with increasing altitude, keeping R constant with commensurate exponential reduction in the ambient pressure, P. Constant R extrapolations of this sort should be confined to light diving activities, certainly not heavy repetitive, decompression, nor saturation exposures where they are not applicable; and the method was limited by Bassett and Ingle to near 10,000 ft elevation.[7-10]

With contemporary suggestion[7,11] of a 24 hour waiting rule for flying-after-diving, questions naturally arise concerning extensions of the US Navy Tables, particularly the Standard Interval Table, to accommodate the longer required interval. In the past, the 120 minute compartment was employed to control altitude excursions within 12 hour intervals. But, the 120 minute compartment is too short to control altitude excursions over 24 hour intervals. So one obvious solution is the assignment of an even slower compartment, with smaller critical tension (M-value), to control altitude excursions, of which flying-after-diving is just one special case. The altitude analyses Bühlmann[2], incorporating a 635 minute tissue compartment, are pertinent in this regard, and we can construct a set of altitude procedures, based on the similarity method, which incorporate the 635 minute compartment. But before so doing, a brief review of the conservative similarity method for altitude diving is first warranted. The similarity method is conservative because critical parameters, such as tensions and decompression ratios, are always less than the those employed in the tested table schemes of Bühlmann[2] and Bell and Borgwardt[4], as also noted by Nishi,[7] Ingle,[7] Bassett[10] and Wienke.[6,11]

Similarity rule

Requiring decompression ratio, R, constancy at altitude induces a necessary scaling of actual depths to sea level equivalent depths for table entry, with times remaining unchanged. Actual depths at altitude are multiplied by factors, α, called altitude correction factors, which are just the ratios of sea level ambient pressure to altitude ambient pressure. Today, accurate wrist altimeters facilitate rapid, precise estimation of *a* on site. They are simply estimated from the barometer equation and are always greater than one. Table 1 lists correction factors in multiples of 1,000 ft of altitude. The higher one ascends to dive, the deeper is the relative exposure in terms of sea level equivalent depth. As ambient pressure decreases correction factors increase rapidly above 10,000 ft.

TABLE 1

ALTITUDE CORRECTION FACTORS AND USN ALTITUDE GROUPS.

altitude or change (ft)	ambient pressure P (fsw)	correction factor α	penalty group on arrival at altitude	permissible group for ascent to altitude
0	33.00	1.000		
1,000	31.86	1.036	A	L
2,000	30.77	1.072	B	K
3,000	29.67	1.112	B	J
4,000	28.55	1.156	C	I
5,000	27.50	1.200	D	H
6,000	26.53	1 244	E	G
7,000	25.45	1.292	E	F
8,000	24.55	1.344	F	E
9,000	23.63	1.396	G	D
10,000	22.72	l.452	H	C

From Table 1, P and α are seen to be reciprocally related, inverses actually. Again, time is measured directly, that is, correction factors are only applied to underwater depths, ascent rates and stops. The 3% density difference between salt and fresh water is not important when computing sea level equivalent depths. Neglecting the 3% correction in computing sea level equivalent depths falls on the conservative side, because the correction decreases equivalent depth by 3%. The effect on ascent rate or stop level is not conservative, but is so small in actual application that it can safely be neglected.[9,11] Recall that the 3% correction is neglected when using US Navy Tables in fresh water.

The similarity rule for altitude table modification and applying correction factors to calculations is straightforward. Convert depths at altitude to sea level equivalent depths through multiplication by α. Convert all table sea level stops and ascent rates back to actual altitude through division by α. Ascent rates are always less than 60 ft/min, while stops are always shallower than at sea level. Thus, a diver at 60 ft.at an elevation of 5,000 .ft uses a depth correction of 72 ft, using $\alpha = 1.2$. The corresponding ascent rate is 50 ft/min, and a stop at 10 ft at sea level translates to 8 ft at this elevation..

If a diver has equilibrated with ambient pressure at any elevation, then any reduction in ambient pressure will put the diver in a repetitive group, merely because tissue tensions exceed ambient pressure. If the original and new pressures are specified, it is possible to estimate tissue saturation and, hence, repetitive group for the excursion. Similar comments apply to pressure reductions following any diving activity, with sea level diving being the standard case. These considerations are treated as follows.

At sea level, each repetitive group represents an increment of tissue pressure over (P = 33 fsw). For the US Navy Tables, this increment is 2 fsw (absolute). If we compute the difference between sea level pressure and altitude ambient pressure, and then scale the difference by the ratio of sea level ambient pressure to altitude ambient pressure (α), we can estimate the repetitive group in which a sea level diver finds himself following immediate ascent to altitude. These group specifications are listed in column 4 of Table 1 and represent penalty time for the excursion to altitude. Entries were computed using sea level as the baseline, but are also appropriate (conservative) for any excursions between differing elevations.

In similar fashion, excursions to higher altitude following diving are limited by tissue critical tensions, and minimal repetitive group designators can be attached to any planned excursion. For the 120 minute compartment, the surfacing critical tension (sea level) is 51 fsw (nitrogen pressure) in the US Navy Tables. To be safer, we take 47 fsw as the limiting tension, convert it to an absolute tension of 60 fsw (47/.79), and then inversely scale it to altitude by the ratio of sea level pressure to altitude pressure, that is, α. The resulting limiting tensions at altitude can then be converted to standard US Navy groups, as tabulated in column 5 of Table 1. Entries represent maximum permissible groups for immediate altitude excursions, and do not account for any travel time. Thus a diver would have to wait some length of time after a dive, until he dropped into the permissible group category, before ascending. The D-group rule for flying after diving is seen as a special case for an altitude excursion to 9,000 ft (maximum cabin pressure). For 10,000 ft, the rule would be wait until C-group here. Both are one group less than the earlier Smith[9] recommendations because a smaller critical tension (47 fsw) was employed in calculations.

Having assigned groups for altitude excursions, we can now turn to the question of permissible time intervals (delays) for excursions, more particularly, the Standard Interval Table with a 635 minute controlling compartment Use of a 635 controlling compartment will increase delay times for altitude excursions compared to previous recommendations[7,9,11] based on the 120 minute compartment in the US Navy Tables.[3]

Interval table modifications

The calculation of permissible time for an altitude excursion following a dive, or flying-after-diving, amounts to determining the permissible altitude group from Table 1, the repetitive group following the dive, the standard (US Navy) surface interval to drop into the permissible altitude group, and multiplication of that surface interval by roughly 5.4. The factor of 5.4 results from replacement of the US Navy 120 minute compartment by the 635 minute compartment in the Surface Interval Table, so that intervals times are increased by roughly 635/120 plus rounding calculations at group boundaries. For given repetitive group and altitude excursion (change in elevation), Table 2 lists minimum delay times for altitude excursions as a function of altitude and repetitive dive group. Entries are consistent with a 635 minute compartment controlling off-gassing, and 47 fsw limiting dissolved gas build up in that compartment.

Note in Table 2 that 24 hours and 50 minutes are required before ascending to an altitude of 10,000 ft, if one is in repetitve group L. This delay is consistent with the current 24 hour delay recommended before flying-after-diving.

Summary

This procedure was developed to assist divers in assessing adequate post-diving delay before flying or ascending to altitude.[12] It is ultimately based on the US Navy Tables, assuming a 635 minute controlling compartment for altitude excursions. Overall, the procedure is quite conservative and consistent with the contemporary 24 hour rule for flying-after-diving because:

TABLE 2

REPETITIVE GROUPS AND MINIMUM DELAY TIMES FOR ALTITUDE EXCURSIONS

Altitude or change	**Repetitive group**								
ft	D	E	F	G	H	I	J	K	L
2,000	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	2:26
3,000	0:00	0:00	0:00	0:00	0:00	0:00	0:00	2:37	4:08
4,000	0:00	0:00	0:00	0:00	0:00	0:00	2:53	4:30	5:51
5,000	0:00	0:00	0:00	0:00	0:00	3:04	4:57	6:29	7:44
6,000	0:00	0:00	0:00	0:00	3:20	5:24	7:12	8:38	9:54
7,000	0:00	0:00	0:00	3:41	6:02	8:06	9:43	11:10	12:36
8,000	0:00	0:00	4:08	6:50	9:11	11:04	12:41	14:19	15:40
9,000	0:00	4:50	8:06	10:48	12:58	14:51	16:39	18:11	23:09
10,000	6:18	10:37	13:25	15:56	18:05	20:10	21:18	23.24	24:50

1 The extrapolation (exponential) of critical tensions (M-values) to altitude is even more conservative than the tested (linear) schemes of Bühlmann[2] and Bell and Borgwardt[4] below 10,000 ft;

2 The introduction of a 635 minute controlling compartment requires longer surface intervals.

Other factors[11] certainly affect the diver at altitude. We mention two briefly in closing, in the interests of safety and operational procedures.

Buoyancy changes occur when divers move between fresh and salt water, or different elevations. Since fresh water is less dense than salt water, buoyancy is lost in fresh water relative to salt water. Similarly, since ambient pressure at altitude is less than at sea level, wet suits expand at elevation, increasing buoyancy. Effects, however, tend to offset each other. The increased wetsuit buoyancy amounts to roughly .2% of body weight for each multiple of l,OOO ft elevation. The fresh water decrease in buoyancy, relative to salt water, is approximately 2.5% of total diver weight.

Capillary, diaphragm, and Bourdon depth gauges are usually calibrated at sea level in salt water. Fresh versus salt water reading errors alone, as with buoyancy changes, are small, but all register increasing error with increasing altitude for actual depth. Diaphragm and oil-filled gauges indicate depths that are shallower than the actual depth, while capillary gauges indicate depths that are deeper than the actual depth. But the capillary gauge is a blessing in disguise at altitude, since it automatically registers sea level equivalent depths for table entry.[9,11] Today, same gauges are available that are adjustable for re-zeroing at altitude, circumventing the problem except for the 3% density correction. In any case, a few simple rules suffice for correcting salt water, sea level gauges at altitude. To obtain actual depths from capillary gauge readings, subtract 3.5% of the reading for each 1,000 ft increment of elevation. For all other gauges, add 1 .ft for each 1,000 ft increment of elevation, and then add 3% of the reading.

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This is a revised version of a paper "Another Approach of Altitude Delay" by the same authors which appeared in Sources 1991; Nov-Dec: 43,45. It is printed here by kind permission of the Editor of Sources.

WHO'S MORE AFRAID, WHO TAKES THE RISKS, MEN OR WOMEN?

Clinical psychology graduate student Edith Hoffmann from Miami's Barry University recently conducted a study to determine whether male or female divers exhibit greater anxiety and risk-taking behaviour. Her research was carried out in cooperation with Quiescence Diving Services in Key Largo, Florida.

Thirty nine male and 39 female sport divers were chosen from 100 respondents. Excluded were those who were under 19 years of age, had not dived within the past six months, or did not dive with their regular buddies; included, however, were those subjects who generally dived with different partners.

Using an accepted test to assess how respondents "feel right now" and how they "generally feel", Hoffmann found no significant difference anxiety levels of male and female divers.

Surprisingly, *male and female divers, as a group, were significantly calmer before diving than they reported being in their everyday lives.*

To determine the extent to which divers engage in risk-taking behaviour, Hoffmann developed a scale which assesses risks divers take in the maintenance of their scuba equipment, with their physical health and mental well-being, and in adherence to diving rules.

The results showed significantly higher levels of risk-taking behaviour in male than in female divers.

Thirty-six percent of the male divers violated the commandment "never dive alone", whereas eight percent of the women had dived without a buddy.

Forty-three percent of the men admitted to diving with a hangover compared to five percent of female divers.

Both female and male divers succumbed to peer pressure when they were hesitant to make a dive. The female divers led with 46 percent, followed by the male divers with 33 percent.

No correlation was found between anxiety and risk-taking behaviour. Of the male divers with low anxiety, 38 percent took low risks, 51 percent moderate chances, and 11 percent exhibited high risk-taking behaviour. Of the female divers with low anxiety, 65 percent took low risks, 31 percent took moderate chances, and one woman exhibited high risk-taking behaviour.

Hoffmann concludes that risk-taking behaviour may not be affected by anxiety and may be a matter of choice. The tendency toward risk-taking is culturally defined in some males.

However, just as men who are very sure of themselves as human beings reject the "male" role of taking chances, some female divers take more risks than expected to ensure their safety and that of their diving buddies.

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The address of UNDERCURRENT is P.O. Box 1658, Sausalito, California 94965, USA.

GLEANINGS FROM MEDICAL JOURNALS

The following articles have come to the notice of the editorial staff and these notes are printed to bring them to the attention of members of SPUMS. They are listed under various headings of interest to divers. Any reader who comes across an interesting article is requested to forward the reference to the Journal for inclusion in this column.

ENRICHED AIR (NITROX)

Evaluating enriched air ("nitrox") diving technology
Hamilton RW.
Abstract

This report summarizes the findings of a group of diverse experts examining the means for proper practice of enriched air or "nitrox" diving, which employs mixtures of oxygen and air having oxygen percentages between 23 and 50% and the balance nitrogen. The group endorsed the NOAA exposure limits for preventing CNS oxygen toxicity (maximum exposure 1.6 atmospheres PO_2 for 45 minutes) as physiological limits, but felt lower limits should be taught. It was concluded that equivalent air depth decompression table computations are valid and should be reliable if based on reliable tables. DCS/embolism treatment procedures good for air diving are entirely appropriate and should be equally effective for enriched air diving. The oxygen exposure during recreational-type enriched air dives within the NOAA limits would have a minimal effect on subsequent treatment for decompression sickness, and if kept below the CNS limits would not be likely to cause any other oxygen exposure problems. Air used for preparing mixtures should be oil free and acceptable for oxygen service, preferably from an oil-free compressor; a specification for "oil-free" air has yet to be written. Booster pumps for final compression into scuba tanks have to be oil free or compatible with oxygen service. If enriched air is mixed in scuba tanks, tanks should be cleaned and equipped for oxygen service. Pending confirmatory testing, prepared mixes can be used in standard scuba gear under rigorously enforced conditions: Oxygen must not exceed 40% at any time, oxygen compatible lubricants must be used, and air must be oil free. Mixing in standard tanks by filling initially with oxygen and topping with air is considered unsafe and should not be practiced or condoned. Standard scuba tanks may be used for mixing only if prepared for oxygen service. Enriched air mixtures do not corrode tanks or equipment any faster than air, but gas must be kept dry. Mixtures should be analyzed after stabilizing and before use. Dive shops desiring to dispense enriched are encouraged to acquire premixed gas from an industrial gas supplier. Existing training agencies for enriched air ("nitrox") are accepted as adequate, but they are to co-ordinate their teaching and develop a uniform standard for enriched air divers, instructors, and dispensers; additional agencies conforming to a uniform standard are encouraged. Specific remaining tasks were identified: A new commodity specification for oxygen-enriched air in the range of 23-50% should be prepared, a unique tank connector for this mixture should be designed and testing of flammability of standard equipment in the range of 40-50% oxygen should be performed. A working group was established to implement these and other needs.

From the Workshop Findings of a Symposium, held in January 1992, sponsored by Scuba Diving Resource Group, P.O.Box 3229, Boulder, Colorado 80307, U.S.A.

PATENT FORAMEN OVALE

Safety of subaqua diving with a patent foramen ovale
Cross SJ, Evans SA, Thomson LF, Lee HS, Jennings KP and Shields TG. Brit Med J 1922; 304: 481-2 (22 Feb)

Patent foramen ovale and subaqua diving (Letter)
Wilmshurst P. Brit Med J 1992: 304 1312 (16 May)

Patent foramen ovale and subaqua diving (Reply)
Cross SJ, Evans SA, Thomson LF, Lee HS, Jennings KP and Shields TG. Brit Med J 1922; 304: 1312

AFTER RESCUE COLLAPSE

Circum-rescue collapse; collapse, sometimes fatal, associated with rescue of immersion victims.
Golden F St C, Harvey GR and Tipton J. J Roy Nav Med Ser 1991; 77: 139-149.

This article deals with the fact, first reported during the Second World War, that many people rescued from immersion in cold water died very quickly after being pulled out of the water. The same has happened since and these authors have investigated this phenomenon. They have come to the conclusion that, although hypothermia does affect the victims of immersion, the best explanation for collapse during rescue is not the after drop effect of hypothermia but a failure of the body to vasoconstrict enough to compensate for the loss of the mechanical support that the immersion in water gives. They have shown that, in health volunteers, a vertical lift out of water causes a heart rate increase of about 20% while a horizontal lift increases the heart rate less than 5%. The hypothermic person being rescued is unable to increase his cardiac output sufficiently when lifted vertically out of the water.

They recommend that nobody should be lifted from the water in a vertical lift with a single strop, as this is associated with many collapses. Preferably they should be lifted horizontally which reduces the heart rate change. If there is not a stretcher that can be put under the person being rescued, it is best to use two stops to lift with. One that goes round the chest and another under the knees. This keeps the victim as near horizontal as possible.

DIVING MEDICINE REVIEW

Medical problems associated with underwater diving
Melamed Y, Shupak A and Bitterman H. New England J Med 1992; 326 (1): 30-35.

A review article, presented in Current Concepts, covering barotrauma, decompression sickness, nitrogen narcosis.and treatment for these illnesses written simply but comprehensively. There are 51 references.

ABSTRACTS FROM THE 1991 ANNUAL SCIENTIFIC MEETING OF THE UNDERSEA AND HYPERBARIC MEDICAL SOCIETY

The address of the Undersea and Hyperbaric Medical Society is 9650 Rockville Pike, Bethseda, Maryland 20814, U.S.A.

DECOMPRESSION ILLNESS

An analytic survey of 111 cases of decompression sickness.
Robertson AG. *Undersea Biomed Res* 1991; 18 (Supp): 47.

Decompression sickness (DCS) follows a reduction in evironmental pressure sufficient to cause the formation of bubbles from gases dissolved in body tissues. DCS may produce long term health effects even after treatment. The purpose of this study was to identify factors associated with a poor outcome in DCS which may be predictive of an increased risk of incomplete recovery. An analytical survey was conducted of 111 divers who had presented to the HMAS STIRLING recompression facility for treatment between 1984 and 1990. Univariate analysis showed that treatment delay and type of DCS were strongly associated with poor outcome. Logistic regression analysis identified various predictors of outcome. Delay of greater than 48 hours, spinal cord disease, other neurological disease and absence of diving qualifications, were the best predictors of poor outcome. The major implications of these findings were twofold. Firstly, the factors associated with poor outcome in decompression sickness provide a basis for defining high risk patients at the time of diagnosis and will assist in the development of a new disease classification system. Secondly, this study has generated a number of hypotheses which require further research, particularly in the areas of delayed treatment in different types of DCS and the cost-benefits of the different types of transportation and treatment currently available.

From HMAS STIRLING, PO Box 228, Rockingham, Western Australia, 6168.

Risk assessment of asthma for decompression illness.
Corson KS, Dovenbarger JA, Moon RE, Hodder S and Bennett PB. *Undersea Biomed Res* 1991; 18 (Supp):16-17.

Asthma has traditionally been considered a significant risk factor for decompression illness, particularly arterial gas embolism (AGE). In order to assess the risk of asthma for AGE and decompression sickness (DCS) a retrospective review was made of DAN accident data covering the four years 1987-1990. A total of 1,213 cases of decompression illness had been reported to DAN at the time of this writing, of which 196 had suffered AGE based upon the clinical diagnosis of the treating physician. 755 had suffered type II DCS. In this accident group there were 54 divers who had a history of asthma, of which 25 were currently asthmatic (defined as having had an attack within one year or taking bronchodilator therapy). 16 divers with AGE had a history of asthma, of which 7 were currently asthmatic; 30 divers with type II DCS had asthma, of which 16 were currently asthmatic. In order to provide a control population 1,000 questionnaires were resent out to a randomly selected group of DAN members; 696 questionnaires were returned. Of these control individuals 37 divers admitted to a history of asthma, of which 13 were currently asthmatic. Odds ratios were calculated in order to establish the ratio of the probability of each condition (AGE and type II DCS) in a diver with asthma compared to the same probability without asthma. Results are shown in the table

Condition	Odds Ratio	95% Confidence Interval	P
AGE			
all asthmatics	1.58	0.80 - 2.99	ns
current asthmatics	1.98	0.65 - 5.33	ns
Type II DCS			
all asthmatics	0.74	0.43 - 1.24	ns
current asthmatics	1.16	0.51 - .259	ns

below:

We were unable to demonstrate a statistically significant increase in risk for Type II DCS in asthmatics. The data suggest an approximately two-fold increase in risk for AGE in asthmatics but the data does not reach statistical significance. On the basis of these data it appears that the incremental risk of AGE in the asthmatics in this sample population is small. A definitive study will require a much larger sample.

From the Divers Alert Network and FG Hall Hypo/Hyperbaric Center, Duke University Medical Center, Durham, North Carolina, USA.

Patent foramen ovale (PFO) and decompression illness.
Moon RE, Kisslo JA, Massey EW, Fawcett TA and Theil DR. *Undersea Biomed Res* 1991; 18 (Supp): 15.

Right-to-left shunting through a PFO provides a mechanism by which venous gas emboli can enter the arterial circulation. Evidence suggest that PFO is a risk factor for decompression illness (DCI). 90 divers with previous DCI were studied using bubble contrast echocardiography (BCE) and color flow doppler (CFD) imaging in order to detect right-to-left shunt through a PFO. Of these divers 59/90 had experienced serious symptoms (defined as weakness, cerebral symptoms or difficulty with balance); 31/90 divers had experienced pain or sensory symptoms only. A control group of similar age and sex distribution were also studied. After CFD imaging, BCE was performed on each subject during resting breathing (R) while 10 ml of agitated saline was injected IV. If shunt was not evident, repeat injection was administered during the release phase of each of 2-3 Valsalva manoeuvres (V). Images were interpreted by a cardiologist unaware of whether the subject was a diver or control. The percentage of subjects with right-to-left shunt detected by BCE and odds ratios (OR[95% confidence interval]) are shown below:

Shunt	Controls (%)	Serious DCI (%)	P	OR
R or V	19.8	49.2	.0002	3.9 [1.8-8.4]
R only	10.9	37.3	.0002	4.9 [2.0-12.2]
V only	8.9	11.9	.743	1.4 [0.4-4.4]

Shunt	Controls (%)	Non-serious DCI (%)	P	OR
R or V	19.8	35.5	0.119	2.23 [0.82-5.82)
R only	10.9	19.4	0.355	1.96 [0.54-6.47]
V only	8.9	16.1	0.419	1.97 [0.47-7.19]

There was a statistically significant relationship between PFO and serious DCI. The presence of a resting shunt increases the risk of serious DCI almost five-fold. The data also suggest increased risk of DCI with shunt after Valsalva but the result is not statistically significant. CFD was poor at detecting inter-atrial shunt: of a total of 60 shunts detected by BCE only one (in a control subject) was detected by CFD.

Depts. of Anesthesiology and Medicine, and Hyperbaric Centre, Duke University Medical Center, Durham, North Carolina, USA.

Comparison of treatment of compressed air-induced decompression sickness by recompression to 6 ATA breathing air and heliox.
Pearson RR, Bridgewater BJM and Dutka AJ. *Undersea Biomed Res* 1991; 18 (Supp): 25.

Acute spinal cord decompression sickness (DCS) was induced in 16 air breathing, pentobarbital anaesthetised, ventilated male dogs by compression at 60 fpm to 300 fsw for 15 minutes followed by decompression to the surface at 60 fpm. Post-decompression lumbar spinal cord somatosensory evoked potentials (SSEP) were recorded every 2 minutes by electrodes at T13/L1 and L1/L2. DCS was deemed to have occurred when the summated amplitude of the peaks of the SSEP signal was below 40% of pre-dive control values for two consecutive measurements. Additional physiological monitoring included systemic arterial blood pressure, right ventricular pressure and arterial blood gases. In the case of 9 dogs where DCS did not occur within 30 minutes of surfacing, a further compression to 300 fsw for 8 minutes was carried out with similar compression and decompression rates. Once the criteria for spinal cord DCS had been met, recompression to 165 fsw was carried out at 60 fpm in an air filled chamber breathing either air (n-8) or 21%/79% oxygen/helium mixture (n-8). SSEPs were recorded at 5 minute intervals for the first 15 minutes and then every 15 minutes for a further 105 minutes. A good albeit incomplete, response to recompression (as judged by SSEP recovery) occurred in all animals with mean 15 minute recoveries to 77% (SD=24) pre-dive control values in air breathing animals and 61% (SD=23) in the heliox group. Thereafter, minor degrees of deterioration occurred in both groups but the mean response of the heliox animals remained below that of those breathing air. There was no statistical significant between the groups as was also the case for the haemodynamic responses. This model of spinal cord DCS generates both autochthonous and intravascular gas bubbles, and the claimed theoretical advantages of a heliox mixture should have been seen to best advantage, particularly with the early resort to therapy once DCS had occurred. As it was there was no demonstrable benefit from the use of a heliox mixture as an adjuvant to recompression. (Supported by NMRDC Work Unit M0099.0IC-1053).

From the Naval Medical Research Institute, Bethesda, Maryland 20814-2089, U.S.A.

Intravascular bubble composition in guinea pigs: a possible explanation for differences in decompression risk among inert gases.
Lillo RS. *Undersea Biomed Res* 1991; 18 (Supp): 24-25.

Differences in risk of decompression sickness (DCS) that have been observed among inert gases may reflect differences in gas solubility and/or diffusivity. A riskier gas might generate a larger volume of evolved gas during decompression thereby increasing the probability of DCS.

If this hypothesis is correct, the composition of bubbles that developed during decompression should reflect such gas differences. These experiments expand on a preliminary report[1] examining bubble composition. Unanesthetized guinea pigs were compressed to depths ranging from 250 to 350 fsw with air, H_e-0_2 (21% 0_2), or one of a number of N_2-H_e-0_2 mixtures or N_2-A_r-0_2 mixtures (21% 0_2). Animals were held at depth from 15 to 60 min, and then decompressed slowly (1 fsw/sec) or rapidly (<15 sec) to 5 fsw. If severe DCS developed as judged by changes in physiological variables, death usually quickly occurred. Gas/blood samples were then immediately withdrawn from the right atrium or the inferior vena cava, and the gas phase analyzed for H_e, N_2, A_r, CO_2 and 0_2 via gas chromatography. Bubbles from all dives contained 5-9% CO_2, 2-6% O_2, with the balance inert gas. Bubbles following N_2-H_e-O_2 dives contained substantially more N_2 than H_e (up to 1.9 times more); bubbles following N_2-A_r-O_2 dives more Ar than N_2 (up to 1.8 times more). For N_2-H_e-O_2 dives, the actual inert gas makeup of bubbles was dependent on the time-at-depth and the decompression profile. Results may reflect differences among H_e, N_2 and A_r in tissue solubility/diffusivity and gas exchange rates, and support the rank order of increasing DCS risk ($H_e < N_2 < A_r$) and rate of gas exchange ($N_2 < H_e$) observed during rat dives.

From the Naval Medical Research Institute, Bethesda, Maryland.

Reference

1 MacCallum ME, Lillo RS and Caldwell JM. Inert gas composition of intravascular bubbles in guineapigs followinf decompression from experimental dives. *Undersea Biomed Res* 1989; 16 (Supp): 30.

Is oxygen inhalation at the decompression stops of any interest in reducing bubble formation? Ducasse JL, Izard PH, Gutierrez N, Masurel G and Cathala B. *Undersea Biomed Res* 1991; 17(Supp): 62.

Material and method

Twenty six healthy subjects (34 year ±16) were submitted to two air simulated dives. The same diving scheme was followed b(30 minutes bottom time at 36 msw), including 2 minute stop at 6 msw and 11 minute stop at 3 msw, according to the French worker's scuba diving table. This scheme was automatically controlled, including gas selection, thanks to the fully computerized chambers of our hyperbaric facility. The kind of gas decompression, air or pure oxygen (O_2), was randomized for each diver who didn't know which gas he was breathing. After each dive, all the subjects were investigated, at rest 9 standing motionless) and after a deep knee bend (flexing), by precordial Doppler bubble detection. This timing was: T=0 minute (opening the chamber), T=30 minute, T=60 minute, T=90 minute and T=120 minute. Each detection was recorded on tape for listening and interpretation according to the K.M code.[1] The mean bubble grade (MBG) was calculated for each diver.

Results

After air decompression and at rest, 5 divers (19%) showed bubble flows. After limb flexion, the MBG normally increased. After $_2$ decompression, only subject No 6 still showed bubble flow at rest. After flexing, 2 more divers (No 10,23) had positive bubble flows. However, in all cases, and for each subject, the MBG was lower at O_2 than at air breathing decompression.

Discussion

	AIR		OXYGEN	
Subject	**At rest**	**Flexing**	**At rest**	**Flexing**
No6	0,6	1,8	0,2	0,4
No10	0,4	1,8	0	0,6
No22	0,4	1,2	0	0
No23	0,6	1,2	0	0,2
No26	0,2	1,4	0	0

The proof of O_2 inhalation efficiency in the prevention of decompression sickness was never achieved. However, these results show that O_2 inhalations at the decompression stops decrease the bubble flows in all the "bubbling" divers.

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References

1 Kissman and Mausrel et al. *Undersea Biomed Res* 1978; 1: 28.

Decompression sickness as an etiology of acute cerebral symptomatology in divers.
Tolsma KA and Arnold AA Jr. *Undersea Biomed Res* 1991; 18 (Supp); 51-52.

It has been the practice to attribute cerebral symptoms to AGE, even when seen in the presence of Spinal DCS. However, it would be preferable to assume a single pathophysiologic mechanism, autochthonous (tissue-based) bubble formation in both cerebral and spinal tissues, especially when the dive and medical histories are not consistent with AGE. Recent animal studies have demonstrated that autochthonous bubbles are common in both spinal cord and cerebral tissues, with the differences in the overall occurrence of spinal and cerebral bubble disease accounted for by the disparity in the gas-clearing blood flow between spinal and cerebral tissues.[1] In support of this hypothesis, we believe that the presence of cerebral bubbles has been demonstrated on clinical grounds as well. During the period of 3/83 through 12/90, 15 cases of Type II DCS with involvement of neural structures rostral to the cervical cord were treated at the Hyperbaric Treatment Center. All histories were carefully evaluated to exclude cases in which CNS symptoms could likely have arisen from other causes (e.g. AGE or migraine). There was a high incidence of concurrent spinal DCS. Consequently, we would suggest that not all cerebral symptoms are due to AGE, but that a significant number are due to autochthonous bubble formation in cerebral and brainstem tissues.

From the University of Hawaii, Hyperbaric Treatment Center, Honolulu, Hawaii.

1 Hardman JM, Beckman EL and Francis TJR. In situ bubble formation in the canine cerebral central nervous system. *Undersea Biomed Res* 1990; 17 (Supp); 138.

Congenital anomaly associated with decompression illness.

Debatin JF, Moon RE, Spriter CE, Woodley J and Gayle P. *Undersea Biomed Res* 1991; 18 (Supp): 45.

A 42 year old female with a history of approximately 15 uneventful dives made a dive to 68 fsw for 35 minutes. After a slow ascent she developed left hemiparesis and difficulty urinating. She was treated with USN table 6 and then a follow up treatment, after which she was asymptomatic. Past history included previous cardiac catheterization showing absent promixal left pulmonary artery. She described having a number of episodes of pneumonia, and a continuing need for antibiotic therapy around six times per year. She denied respiratory infection at the time of her accident. Chest X-ray showed volume loss in the left hemithorax with mediastinal shift to the left. There were diffuse serpiginous peripheral opacities in the hypoplastic left lung, compatible with bronchial collaterals. MRI of the thorax was performed using a gaited spin echo sequence (GE SIGNA 1.5T Scanner: TR = RR; TE = 20/40). Cardiac anatomy was normal, with a right sided aortic arch. The main pulmonary artery fed the right pulmonary artery. Cine images showed no flow to the left pulmonary artery. Pulmonary venous return was normal. A Turboflash sequence confirmed flow to the right pulmonary artery only. No intracardiac shunt was visible on MRI scan and this was confirmed with bubble contrast echocardiography. Pulmonary function tests showed normal lung volumes and vital capacity. There was evidence of mild airways obstruction (FEF_{25-75}51% predicted). We hypothesize that this lady suffered pulmonary barotrauma due to air trapping within the left lung and transpulmonary passage of gas into the bronchial circulation, resulting in cerebral gas embolism.

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Case control study of decompression illness using $^{99}Tc^{m}$-HMPAO SPECT

Hodgson M, Smith DJ, MacLeod MA, Houston AS and Francis TJR. *Undersea Biomed Res* 1991; 18 (Supp): 17: 5.

In a preliminary report in 1989, Adkisson et al. used $^{99}Tc^{m}$-HMPAO SPECT to provide evidence for cerebral perfusion deficits in 28 cases of dysbarism.[1] The report caused concern because these deficits were found even in cases in which the clinical manifestations were apparently limited to the spinal cord.

To address this issue further, a case-control study of cerebral perfusion using $^{99}Tc^{m}$-HMPAO SPECT is presented. Four groups of 10 subjects were studied: a) divers scanned on average 11 days after treatment for neurological decompression illness (DCI). b) divers scanned three to five years after treatment for neurological DCI, c) diver controls, and d) population controls. All groups were matched for age and the divers were further matched for general diving experience. The scans were randomized and reported blind to history. Experience with the technique suggests that only perfusion deficits of 12% or greater are of probable clinical significance. Using this criterion, 8 new cases, 6 old cases, 5 diver controls and 5 non-diver controls demonstrated ‘significant’ deficits. Despite a trend towards larger numbers of deficits in individuals with DCI, the four groups were statistically indistinguishable. No correlation was found between the location of the perfusion deficits and the clinical presentation in the two groups with a history of DCI. There was a higher proportion of positive results in the diver and population controls than might be expected even using high percentage cutoffs. This was surprising since no abnormalities were found in their history or on careful clinical examination.

We were unable to find other published $^{99}Tc^{m}$-HMPAO SPECT series reporting controls with which we could compare our data. One explanation for these findings is that DCI generates a diffuse cerebral injury for which the scan is insufficiently sensitive to discriminate from normal variation, thereby producing an unacceptably high false-positive rate as presently analyzed. With the lack of a distinct positive/negative split, this study has insufficient statistical power for firm conclusions to be drawn. However, these results do indicate that $^{99}Tc^{m}$-HMPAO SPECT scanning requires further evaluation before clinical significance can be ascribed to perfusion deficits found in divers.

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Reference

1 Adkisson GH, MacLeod MA, Hodgson M, Sykes JJW, Smith F, Strack C, Torok Z and Pearson RR. Cerebral perfusion deficits in dysbaric illness. *Lancet* 1989; 2: 119-121.

Estimation of PO_2 in tissues for computations about the oxygen window for decompression bubbles. Van Liew HD and Conkin J. *Undersea Biomed Res* 1991; 17(Supp): 65-66.

The gradient of inert gas betwen a bubble and the tissues is known as the "oxygen window" or "inherent unsaturation". Few pertinent measurements have been made. The process for estimating the tissue PO_2 and PCO_2 is as follows: enter a blood-gas nomogram with alveolar PO_2-PO_2 pairs to get O_2-CO_2 content pairs for arterial blood, account for metabolic removal of O_2 and addition of CO_2 in the tissue to get O_2-CO_2 content pairs for venous blood, and then reenter the nomogram to translate these back to PO_2-PCO_2 pairs: window = PaP_2+$PaCO_2$-PvO_2-$PvCO_2$, where subscripts a and v signify arterial and venous. Calculations for air-breathing subjects over a wide range of pressures show that in hyperbaric environments, the window increases as a straight-line function of ambient pressure until it levels off at values as great as 200 kPa at very high pressures. In contrast, the window is only 1 or 2 kPa for air breathing in extreme hypobaric environments where ambient pressure is below 60 kPa. Breathing of pure oxygen increases the window for any ambient pressure by a factor of 5 or 6 in hyperbaric environments and by a factor of 20 or 30 in hypobaric environments.

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