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To provide information on underwater and hyperbaric medicine.
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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 system 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

There should be no full stops after the reference numbers. There should be a space after the semi-colon after the year and another after the colon before the page number and no full stop after the page numbers. The Journal uses two spaces after a full stop and before and after the journal name in the reference. The titles of books and of quoted journals should be in italics.

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Any report of experimental investigation on human subjects must contain evidence of informed consent by the subjects and of approval by the relevant institutional ethical committee.

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SPUMS ANNUAL SCIENTIFIC MEETING 1996

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

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P.O. Box 120, Narrabeen, N.S.W. 2101.

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DIMS is an ongoing study of diving incidents. An incident is any error or occurrence which could, or did, reduce the safety margin for a diver on a particular dive. Please report any incident occurring in your dive party, but do not identify anyone. Most incidents cause no harm but reporting them will give valuable information about which incidents are common and which tend to lead to diver damage. Using this information to alter diver behaviour will make diving safer.

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

PROJECT PROTEUS

The aim of this investigation is to establish a data base of divers who dive or have dived with any medical contraindications to diving. At present it is known that some asthmatics dive and that some insulin dependant diabetics dive. What is not known is how many. How many with these conditions die is known. But how many dive safely with these conditions is not. Nor is incidence of diving accidents in these groups known.

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

Write to
Project Proteus
PO Box 120, Narrabeen, New South Wales 2101, Australia.

The Editor's Offering

A Happy Christmas and Prosperous New Year to all our readers. For the first time the December issue is going to the printer before the end of November. Allowing 10 working days for printing and to for mailing this issue should be on its way to members by the 13th of December, which means that for many it will arrive in time for Christmas. What better Christmas present can a diving doctor look forward to? Of course there are many, but we hope that this one will give the grey cells food for thought.

In 1995 the Annual Scientific Meeting (ASM) had, for the first time, three sessions where the audience provided most of the input. The two papers constructed from the transcripts appear on 259-272. Two things stand out. The first is that opinions differ on many topics and the other is the power of suggestion. Dr Paton's diving candidate, a man of over 50 and so an "older diver" would have been passed without a murmur at the end of the history and examination but after a discussion on stress ECGs very few were still of the same opinion! When the Editor started doing diving medicals 24 years ago 60, not 50, seemed a reasonable age to define an older diver. Unfortunately time ran out before the discussion got round the defining the older diver.

One must remember that roughly one third of people who complete a diving course never dive again after the course and another third only dive for a year or two. That leaves one third who go on diving for more than two years, the enthusiasts. Those who attend SPUMS ASMs are undoubted mostly the latter which may colour their views. As a large proportion of divers who get into trouble during a dive are inexperienced, or have not dived for a long time, perhaps the best way to reduced diving problems would be to modify training programs so that trainees learn how to avoid running out of air and how to drop their weight belts as these two are common causes of accidents and deaths. This might be more effective in reducing accidents than more medical investigation of learner divers. Older divers who dive regularly (enthusiasts) seldom come for repeat medicals. Unfortunately no one questioned the audience about when they had their last medical!

Of course many of the audience, like the general population of Australia and New Zealand, were overweight to some degree and most of them use the general description of an older diver as one who is older than I am! While age may be the one unavoidable factor in atherosclerosis it does not mean that everyone will die suddenly of myocardial infarction while diving during their later years.

Cardiac death is now the commonest cause of death in American divers over 50 but there are many who only have one risk factor for coronary disease and according to Dr Bove, a diver and cardiologist, this will only raise the risk to 1.2 of the non-risk population. That seems to the Editor to be a very small, and highly acceptable, risk of developing atherosclerosis. What diving doctors are worried about is sudden death during a dive, but there is, at present, no way of calculating that risk except to say that it is very much higher when the diver has **symptoms** of cardiac disease. What is needed is to quantify the risk of sudden death in the water for those without cardiac symptoms. This is unlikely to be realised as the medical histories of many who die in the water from cardiac deaths are unknown. Often all that is reported to the world is that the pathologist diagnosed a cardiac death.

In the Editor's opinion being able to exercise adequately is much the most important factor in avoiding death in the water from cardiac disease. Five minutes stepping up and down on a high step at 30 steps a minute, using a metronome to step by, is certainly a lot cheaper than a stress ECG and much quicker and easier to do. It is not as accurate as a stress ECG at diagnosing cardiac ischaemia but it does demonstrate the ability to exercise to a level above that likely to be needed during diving training and can bring home to divers the need for improving their level of fitness.

Again in the Editor's opinion, the doctor is not in a position to forbid any activity and expect the word to be accepted unless he or she has **convinced** the patient that this is the best course of action for that patient. Medicine is mainly diagnostic and advisory and the patient must consent to the treatment.

It is well known that many people will try another doctor if the first one does not pass them as fit to dive and in younger people the usual cause for rejection is asthma. According to the statistics gathered by the Diver Alert Network (DAN) the proportion of diving deaths with a history of asthma is equivalent to the proportion of asthmatics in the US. Obviously it is more dangerous to dive with asthma than without, but how much more dangerous? Of course every diving death in asthmatic is a disaster which would have been avoided if they had not been diving. But much the same can be said of any diving death. Various authorities take widely differing positions on asthmatics diving, from prohibition to allowing diving four hours after an attack to as long as there is no active wheezing. They cannot all be right. Because most asthmatics still diving have hidden the fact it is difficult to assess how many asthmatics dive. If our readers could ask around their diving friends the Editor expects that there would be some who are asthmatics who dive or have dived. These are the people that Project Proteus (*SPUMS J* 1995; 25 (1): 23-24) is trying to contact in order to establish a data base about asthmatics who dive and the problems they have or did not have. The address to write to is on the back cover.

ORIGINAL PAPERS

ONE HUNDRED DIVERS WITH DCI TREATED IN NEW ZEALAND DURING 1995

Marysha Gardner, Christine Forbes and Simon Mitchell

Key Words

Decompression illness, hyperbaric oxygen, tables, treatment, treatment sequelae.

Introduction

The 1995 calender year was the busiest in the history of the Royal New Zealand Navy Hospital with 100 cases of decompression illness (DCI) treated at the Slark Hyperbaric Unit (SHU). This contrasts with 24 cases in 1990, 31 in 1991, 55 in 1992, 68 in 1993 and 48 in 1994. Demographic data describing this patient population is presented in the following report.

Methods

Relevant parameters pertaining to each case were recorded on a Microsoft Access 2 database maintained by SHU staff. In most cases data entry occurred during the patient's admission, although some records were obtained retrospectively from the patient notes. In selection of data fields, details of the diving incident leading to DCI were not emphasised since these data are forwarded to the Diving Incident Monitoring Study (DIMS) at Adelaide and will be reported elsewhere.

Age and gender of divers

The age of divers ranged from 17 to 64 years, with a mean of 34.0 (SD ± 9.7). Ten divers were female (17 to 49 years, mean 30.5) and 90 male (17 to 64 years, mean 34.5).

Past diving history

Only six divers confirmed that they had received no instruction from a recognised diver training agency. Five divers suffered DCI resulting from entry level training dives. All other divers held recognised diving qualifications although the level of qualification was not recorded in seven. The divers are grouped according to the highest diving qualification held in Table 1 and according to the agency from which they received that training in Table 2.

TABLE 1.

HIGHEST DIVING QUALIFICATION HELD BY DCI PATIENTS.

Highest diving qualification	
Open water diver	40
Advanced open water diver	18
Rescue diver	5
Divemaster	6
Instructor	5
Commercial (HSE Part I)	1
Under training (open water)	3
Under training (resort course)	1
Under training (Navy)	1
Trained but qualification level unknown	7
No qualification or formal training	6

TABLE 2

TRAINING AGENCY PROVIDING HIGHEST QUALIFICATION

PADI	65
CMAS	9
NAUI	5
SSI	5
RNZN	1
US Navy	1
Commercial	1
No qualification or formal training	6
Training history not recorded	7

The number of dives before the dive resulting in DCI ranged from 0 to 4,500 (mean 366 SD ±707). The percentages of divers with less than 20 and 100 dives before their episode of DCI were 40% and 62% respectively. The mean previous deepest depth before the episode of DCI was 20 m.

Seasonal incidence

The peak incidence of DCI was in the summer months of January and February. Numbers of DCI cases are shown by month in Figure 1.

Nature and location of diving

All divers were air diving using scuba equipment with the exception of one diver using a "hookah" (surface supply from a compressor) and one making a chamber dive.

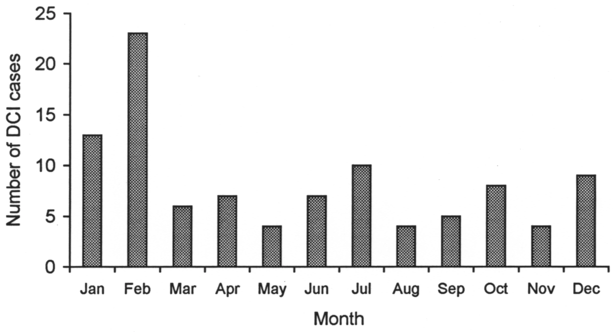

Figure 1. Monthly numbers of DCI patients in 1995.

Ninety were diving for recreation, and 10 for commercial purposes.

Eighteen divers used no recognised dive table or computer. Dive computers were used by 21 divers, and dive tables were used by 52. The means of assessing decompression status, if any, was not recorded for nine divers. The divers are grouped according to the method of decompression status assessment employed in Table 3. Analysis of the reported dive profiles preceding the episode of DCI showed that 39% of divers using dive tables complied with the limits of the table used, whereas 24% of the reported profiles complied with the limits of the Canadian Defence and Civil Institute of Environmental Medicine (DCIEM) table.[1]

Seventy six divers had been diving in New Zealand's North Island, with only 15 in the South Island and nine in the South Pacific Islands.

Referral and transport to the SHU

Divers were usually referred to the New Zealand Diver Emergency Service (DES), based at the SHU, by a local doctor, a local hospital, or by themselves. The frequencies of the various means of referral are given in Table 4. Eighty one of the divers were evacuated, or presented, from the North Island, 13 from the South Island, and six from the Pacific Islands. The frequencies of use of the various means of transport to the unit are given in Table 5. The time from surfacing after the last dive to arrival at the SHU ranged from less than one hour to 28 days (mean 68 hours, SD ±99.6).

Presentation of DCI

The delay to symptom onset varied from immediately on surfacing to 72 hours after diving (mean 8 hours, SD 13.3). Musculoskeletal pain was the most commonly reported symptom. Forty five divers had objective signs when assessed at the SHU. The percentage incidence of the various symptoms and signs recorded is given in Table 6.

TABLE 3

ASSESSMENT OF DECOMPRESSION STATUS

PADI Recreational Dive Planner	40
Computer	21
DCIEM Air Diving Table	6
US Navy Air Diving Table	5
Bassett Modified US Navy	1
No decompression status assessment	18
Decompression assessment not recorded	9

TABLE 4

SOURCE OF REFERRAL TO DES

Local doctor	36
Hospital	29
Self referral	28
Dive boat operator	3
Ambulance service	2
Dive shop	1
Local police	1

TABLE 5

MEANS OF TRANSPORT TO THE SHU

Private vehicle	37
Fixed wing 1 bar pressurised aircraft	30
Road ambulance	17
Helicopter ambulance	13
Not recorded	3

Treatment

Fifty five divers were recompressed to a maximum pressure of 2.8 bar (equivalent to a depth of 18 m of sea water) according to either a USN Table 6[2] (Royal Navy Table 62) or a Royal New Zealand Navy Table 62A,[3] the latter being an oxygen-helium treatment table of similar decompression pattern and duration to the USN Table 6. The remaining divers received deeper treatments after inadequate symptom resolution during initial treatment at 2.8 bar (18 msw). The frequencies of use of the various initial treatment tables are given in Table 7.

TABLE 6

FREQUENCY OF PRESENTING SYMPTOMS AND SIGNS IN 100 DCI PATIENTS.

Symptoms and signs	%
Pain	66
Fatigue	51
Numbness	51
Tingling	46
Weakness	42
Headache	38
Dizziness	23
Shortness of breath	22
Difficulty walking	21
Cognitive difficulty	18
Visual changes	8
Urinary impairment	5
Cough	5
Itch	4
Loss of consciousness	4
Rash	2
Other	15

TABLE 7

RECOMPRESSION TREATMENT TABLES USED AT THE SHU IN 1995

Treatment table	Maximum depth	Treatment gas	No.	Extended treatments
RN 62 (USN 6)	18 msw	O_2	44	10
RNZN 62A	18 msw	Heliox	11	1
RNZN 1	30 msw	Nitrox/O_2	3	1
RNZN 1A	30 msw	Heliox/O_2	8	0
RNZN 2A	30 msw	Heliox	17	12
RN 63 (USN 3)	50 msw	Air/O_2	5	1
RNZN 63	50 msw	Heliox/O_2	12	5

Daily retreatment with an 18:60:30 table[4] was given until the patient either made a full recovery or experienced no sustained improvement over two consecutive days. The mean number of retreatments was 2.3 (SD ±2.7, range 0-17).

Two divers suffered central nervous system oxygen toxicity manifest as convulsions. In one, the episode occurred 10 minutes into the first oxygen breathing period of a USN Table 6 (RN 62). Post-ictally, this patient was changed to 50:50 oxygen-helium and completed an uncomplicated RNZN 62A. In the second, the episode occurred during the third oxygen breathing period of a USN Table 6. This patient completed the table after a recovery period off oxygen. One diver suffered symptomatic pulmonary oxygen toxicity manifested as mild retrosternal discomfort and cough. These symptoms arose near the end of a maximally extended USN Table 6.

Outcome

Seventy divers were recorded as fully recovered at discharge from the SHU while 30 were discharged with residual symptoms or signs. These groups are compared with respect to age, gender, delay to presentation and compliance with dive tables in Table 8.

Discussion

The record 1995 case load was partly explained by the closure of the hyperbaric unit at Christchurch (South Island) throughout the year, making the SHU New Zealand's only hyperbaric unit. Nevertheless, even if the 13 divers evacuated from the South Island are ignored, the remaining 87 divers still represent an annual record. It is possible that particularly good summer diving conditions and New Zealand's economic recovery led to a substantial increase in diving activity and a consequent increase in the number of accidents.

The largest group of patients was relatively inexperienced divers trained to Professional Association of Diving Instructors (PADI) Open Water level,[5] who were using the PADI Recreational Dive Planner (RDP)[6] to assess decompression status. PADI has been the dominant training agency in New Zealand since 1986 and currently trains 70-80% of new divers. It follows that the patient population reported here is probably representative of the active diving population and nothing can be concluded from such numerator based data. Similarly, without an accurate assessment of the prevalence of diving computers in the diving community, little can be concluded from the control of decompression status by these devices in 21 % of the cases reported here.

Although the reported dive profiles may not be reliable, it is notable that 39 % of patients reported dives within the limits of the table used, and 24 % within the limits of the DCIEM tables. The occurrence of DCI despite adherence to the limits of tables is worthy of emphasis in the training of recreational divers.

The presenting symptoms and signs in these patients were qualitatively and quantitatively similar to those reported in other series.[7] The mean delay to symptom onset after diving was 8 hours, while the mean delay to presentation at the SHU after diving was 68 hours. Although the latter figure may be skewed by the very late presenting patients, there is nevertheless a clear tendency for divers to

TABLE 8

COMPARISON OF PATIENTS MAKING COMPLETE AND INCOMPLETE RECOVERY WITH RESPECT TO AGE, GENDER, DELAY TO PRESENTATION AND COMPLIANCE WITH DIVE TABLES

Variable	Complete recovery	Incomplete recovery
Number	70	30
Age (years)	mean 33.7 (SD ±9.5)	mean 36.0 (SD ±10.4)
Gender		
female (n = 10)	8 (80 % of females)	2 (20 % of females)
male (n = 90)	62 (69 % of males)	28 (31 % of males)
Delay from dive to arrival at SHU (hours)	mean 76 (SD ±109) range 0.5 - 692	mean 48 (SD ±68) range 0.5 - 336
Compliance with tables		
Own	43 %	30 %
DCIEM	29 %	13 %

tolerate, or deny, the often non-specific and subjectively mild symptoms of DCI for a substantial period before seeking help, perhaps in the hope of avoiding the stigma and inconvenience of the diagnosis. Such procrastination should be actively discouraged in recreational diver education.

The selection of recompression treatment tables during 1995 was based in part on the algorithm for the trial of oxygen-helium (heliox) versus oxygen in the treatment of air diving DCI (the heliox trial”),[8] although a number of divers were not entered into this trial. The large group of divers treated deeper than 18 m (2.8 bar) utilising oxygen-helium tables (Table 7) includes both divers treated with oxygen and divers treated with oxygen-helium during the initial period at 2.8 bar (18 m). The relative merits of oxygen or oxygen-helium as the initial treatment gas at 2.8 bar (18 m) cannot be implied from these data. These issues will be clarified when the heliox trial is reported. The approach to initial treatment table selection by Australasian hyperbaric units has been reported elsewhere.[4]

Thirty divers were discharged with residual manifestations of DCI. This is a similar proportion of treatment failures to that reported for Australasian sport diver populations elsewhere[9,10] and underscores that there is no room for complacency about the adequacy of current treatment protocols.[11] There was no difference in the mean age of the complete and incomplete recovery groups or the relative proportions of males and females across these groups. The mean delay to presentation in the complete recovery group was 76 hours, compared with 48 hours in the incomplete recovery group. The inference that earlier presentation predicates a poor outcome is untenable and these data probably reflect earlier presentation of divers with more severe disease. Not surprisingly, divers making a complete recovery were more likely to have complied with the limits of the DCIEM table and/or their own dive table than divers who made an incomplete recovery. These data reflect the likelihood of disease of greater severity following a more provocative time/depth exposure.

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AN UNUSUAL CASE OF CEREBRAL ARTERIAL GAS EMBOLISM

Christopher Butler, David King and David McManus

Abstract

A snorkel diver suffered a cerebral arterial gas embolism after breathing, at depth, from the octopus regulator of a scuba diver. The neurological injury was manifested by loss of consciousness and by cortical blindness. The chest X-ray demonstrated multiple signs of pulmonary barotrauma. An MRI scan demonstrated cerebellar infarction. The unusual aspects of this case and the pathophysiology of pulmonary barotrauma are discussed.

Key Words

Accident, air embolism, barotrauma, cerebral arterial gas embolism, eyes, pulmonary barotrauma, treatment, unconscious.

Introduction

Pulmonary barotrauma and cerebral arterial gas embolism (CAGE) are usually associated with scuba diving accidents. We describe CAGE in a snorkel diver demonstrating a number of unusual features.

Case Report

A previously fit 23 year old male was snorkel diving on the Great Barrier Reef. His snorkel diving experience is unknown. He had never dived with scuba. He dived to a depth of 3-5 m and took several breaths from the octopus regulator of an accompanying scuba diver. Then he made an uncontrolled ascent to the surface.

On reaching the surface he was unconscious and had to be rescued. In the boat he was seen to be pale, tachycardic and tachypnoeic. CAGE was immediately suspected, so he was placed supine. Oxygen was given at a flow rate of 15 l/min using a non-rebreathing mask. After 45 minutes the flow was reduced to 10 l/min. He rapidly recovered consciousness, but appeared to be almost completely blind. No formal assessment of vision was carried out on the boat and the patient had no subjective improvement in his vision before recompression. He had no other symptoms or signs.

Urgent helicopter transfer to the local base hospital was arranged. Examination in hospital, an hour and 50 minutes after surfacing and 30 minutes after leaving the boat by helicopter, demonstrated he had difficulty in recognising shapes but normal visual fields to confrontation. This was unusual as occipital blindness usually, but not always, shows loss of field before loss of acuity. Ocular movements were normal, with both pupils small and reacting directly and consensually to light. Fundoscopic examination showed injected fundi but normal discs and no visible haemorrhages. A chest X-ray demonstrated mediastinal emphysema, subcutaneous emphysema and bilateral pneumothoraces (Fig 1).

These findings were confirmed following transfer to Townsville General Hospital 6 hours after surfacing. An ophthalmological opinion was obtained and the visual changes were considered to be the result of bilateral central retinal artery (CRA) occlusions.

He was initially managed with IV saline, IV lignocaine, a Comex 30 heliox table and bilateral digital ocular massage. He was compressed 6.5 hours after surfacing. His vision had improved considerably 85 minutes into the table, but deteriorated on ascent to 12 m.

He was taken back to 30 m and the table recommenced. After this extra time at depth improvement was sustained on ascent. After his first treatment his vision was 6/9 in both eyes.

The fundi were noted to be normal the following day. He had 3 further hyperbaric oxygen treatments (18 m for

Figure 1. A-P chest X-ray demonstrating bilateral pneumothoraces, (black arrows at the level of left and right second ribs), left mediastinal emphysema (black arrow) and subcutaneous emphysema in the neck (white arrow).

60 minutes with a 30 minute ascent) in the next three days. He was discharged with bilateral 6/5 vision.

A T2 weighted magnetic resonance imaging (MRI) scan was performed 5 days after the accident (Fig 2). T2 is defined as the time constant that describes the exponential decay of the transverse magnetism of a tissue following a radio-frequency pulse (as opposed to T1, which describes the decay of longitudinal magnetism which is faster). In practical terms, T2 scans differentiate an increased water content (oedema) of a tissue well. The scan demonstrated multiple signal abnormalities in the left cerebellar hemisphere. Small abnormalities were also noted within the subcortical white matter of the left frontal lobe. The appearance of these changes was consistent with areas of infarction, but did not correlate with any clinically evident neurological defect.

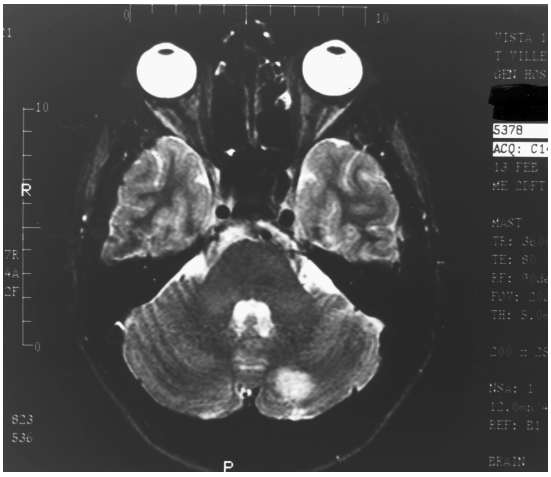

Figure 2. T2 weighted MRI scan of the head showing an area of infarction in the left cerebellar hemisphere.

Discussion

Pulmonary barotrauma, with or without associated CAGE is an important cause of diving fatalities, but the actual incidence is difficult to determine.[1]

It has traditionally been accepted that the combination of pneumothorax and CAGE is uncommon, with an incidence of pneumothorax in divers presenting with CAGE of 5% or less.[2,3] A more recent study demonstrated a higher incidence of other chest X-ray changes indicating pulmonary barotrauma associated with CAGE, but noted that the association with pneumothorax was still uncommon.[4] These studies would indicate that cases demonstrating all the manifestations of pulmonary barotrauma (bilateral pneumothorax, mediastinal and subcutaneous emphysema and CAGE) are rare.

Lung overexpansion and pulmonary barotrauma producing CAGE in divers requires the breathing of compressed gas at depth. Subsequent ascent results in a fall in the ambient pressure and an increased lung volume. Such lung overexpansion is not associated with breath-hold diving from the surface, of which snorkel diving is an example. Two points can be made from this.

1 Snorkel divers when diving with scuba divers are potentially at risk of CAGE if they breathe compressed gas at depth. If a snorkel diver loses consciousness on surfacing, the first aid measures should bear this in mind.

2 Air breathed at a depth of 3 m is sufficient to produce lung rupture on ascent if the diver leaves the bottom with full lungs and does not exhale on the way up. Lung rupture can potentially occur from a depth of 1 m.[5]

The pathophysiology of this patient's blindness was initially confusing. Formal perimetry and fundoscopy, through pharmacologically dilated pupils, were omitted to facilitate early recompression. The only clinical signs of CAGE were loss of consciousness and blindness. The initial diagnosis of bilateral CRA occlusions must postulate that the same terminal branches of two separate carotid circulations were selectively embolised, which is unlikely. The retina is very sensitive to hypoxia as it has minimal collateral circulation. Normal pupillary light reflexes, and a complete return of vision, are not consistent with prolonged total bilateral CRA occlusion. These features make the initial diagnosis of bilateral CRA occlusions very unlikely.

Cortical blindness has previously been described in divers presenting following arterial gas embolism.[6] However it is interesting to note that this most severe clinical abnormality did not correlate with any change in the occipital cortex on MRI scan in this patient. The visual loss was not total, with selective aspects of function being maintained and a full recovery following treatment. This suggests localised and incomplete ischaemia of the distal posterior cerebral artery branches, which are supplied from the vertebro-basilar circulation.

Bubble effects arising from this system are confirmed by infarction of the cerebellum demonstrated on MRI. The loss of consciousness is consistent with transient brain stem ischaemia, which is also supplied by the vertebro-basilar system.

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This case was presented at the Hyperbaric Technicians and Nurses Association (HTNA) Meeting in Hobart in August 1996.

RECOMPRESSION FACILITIES IN PALAU AND CHUUK

Timujin A W Wong

Abstract

During the Second Micronesian Anaesthetic Refresher Course, in October 1995, sessions were devoted to diving and hyperbaric medicine and the pathophysiology and treatment of decompression illness. After the course the hyperbaric facilities of the Belau National Hospital and Chuuk State Hospital were inspected. The January 1993 to October 1995 statistics for the Hyperbaric Unit in Palau were reviewed and the incidence of decompression illness in both regions is discussed.

Key Words

Decompression illness, hyperbaric facilities, teaching, treatment.

Introduction

In October 1995 the Second Micronesian Anaesthetic Refresher Course was held at the Belau National Hospital, Koror, Republic of Palau. Two anaesthetists from the Royal Hobart Hospital, Dr Malcolm Anderson and myself, were the guest lecturers. We were financially assisted by the Australian Society of Anaesthetists (ASA) and the World Federation of Societies of Anaesthesiologists (WFSA). During the organisation of the course, donations of medical products and sponsorship were obtained from: Abbott Australasia Pty. Ltd., Anaesthetic Supplies Australia, Ansell International, Astra Australia, Mallinckrodt Medical, Ohmeda, Organon Teknika, Pacific Medical Supplies Pty. Ltd., Portex, Roche Products Pty. Ltd. and Statemed Pty. Ltd. These companies donated much needed medical supplies to the four regions of Micronesia. QANTAS, Continental Micronesia Airlines and Allways Dive Expeditions Travel Service kindly provided substantial discounts and luggage waivers to enable transport of the medical supplies to, and throughout, Micronesia.

The four day course consisted of lectures in the mornings followed by a series of case presentations and clinical scenarios in the afternoon. The meeting was attended by 14 medical and nursing personnel from the islands of Palau, Yap, Chuuk and Kosrae. The course was structured to cover the essential aspects of anaesthetic care in the areas of trauma, preoperative assessment, anaesthetic emergencies, obstetrics, paediatrics and regional anaesthesia. Also included in the course were sessions devoted to diving and hyperbaric medicine and the pathophysiology and treatment of decompression illness (DCI). These were well-attended by medical and nursing staff and also by a 65 year-old American tourist who had developed mild decompression symptoms before undergoing his first treatment in Palau's new recompression chamber. On one evening, the Palau Pacific Resort provided facilities to deliver a lecture on diving emergencies to local medical staff and diving organisations.

After the course, I stayed in Palau for an additional five days and then a week in Chuuk to participate in further practical teaching in anaesthesia and to review the hyperbaric facilities of the Belau National Hospital and the Chuuk State Hospital.

The Belau National Hospital

The Belau National Hospital is a new establishment, about four years old, and has 120 beds serving a population of approximately 40,000. The medical facilities in Palau were very impressive for such a small island as the hospital was modern and well-equipped. This was in contrast to the very basic conditions found in other Micronesian islands such as Chuuk, Yap and Kosrae. The Belau National Hospital's most impressive acquisition is the new hyperbaric facility. In June 1995, a new multiplace recompression chamber was installed with the help of the US Navy, the National Ocean and Atmospheric Administration (NOAA), the Republic of Palau, the Koror Chamber of Commerce, the Professional Association of Diving Instructors (PADI), the National Association of Underwater Instructors (NAUI), the Divers Alert Network (DAN) and numerous other local and American supporters. The new multiplace recompression chamber replaced an outdated monoplace unit.

Incidence of Decompression Illness in Palau

The January 1993 to October 1995 statistics for the Hyperbaric Unit at the Belau National Hospital (Tables 1 to 4), were provided by Mary Thing, RN. During the 33 month period 46 patients presented after diving accidents, requiring 67 hyperbaric oxygen treatments (Table 1). There is an incidence of 1.3 cases per month and each patient averaged 1.46 treatments. The number of case of DCI treated in Palau has been increasing. In 1993 they had 8 cases, in 1994 there were 16 and from January to October 1995 there had been 22 of these 8 had been treated in the first five months of the year and the unit had treated 14 patients with DCI since the new chamber was installed in June 1995.

The largest age group (18 or 39%) was 20 to 29 years (Table 2). Thirty three (72%) of the DCI cases were aged between 20 and 39. There was a slight trend towards younger patients presenting to the hospital but this was not statistically significant. Thirty two (70%) were male and 14 (30%) were female, a male to female ratio of 2.3:1 (Table 3).

Between January 1993 and October 1995 there were 6 diving related deaths. In 1994 a group of 5 were swept out to the open ocean by strong currents and lost. The single fatality in 1995 was labelled as "drowning by unknown causes while diving" (Table 1).

TABLE 1

DIVING ACCIDENTS TREATED AT THE BELAU NATIONAL HOSPITAL HYPERBARIC CHAMBER JANUARY 1993 TO OCTOBER 1995

	1993		**1994**		**1995**	
Month	**Cases**	**Treatments**	**Cases**	**Treatments**	**Cases**	**Treatments**
January	-	-	-	-	1	1
February	-	-	1	2	2	2
March	1	2	2	2	3	3
April	1	3	3	3	2	2
May	-	-	1	1	-	-
June	1	3	1	3	4	6
July	1	1	0	0	1	2
August	1	1	0	0	6	9
September	-	-	2	4	3	7
October	2	2	3	3		
November	-	-	-	-		
December	1	1	3	4		
Annual total	**8**	**13**	**16**	**22**	**22**	**32**
Diving deaths			**5**		**1**	

TABLE 2

AGES OF DIVING ACCIDENTS VICTIMS TREATED AT BELAU 1993 TO OCTOBER 1995

Age	**1993**	**1994**	**1995 (to October)**	**Total**
< 20	-	-	-	-
20- 29	1	7	10	18
30- 39	2	6	7	15
40-49	3	-	4	7
50-59	2	2	-	4
> 60	-	1	1	2
Total	**8**	**16**	**22**	**46**

TABLE 3

SEX OF DIVING ACCIDENTS VICTIMS TREATED AT BELAU 1993 TO OCTOBER 1995

Sex	**1993**	**1994**	**1995 (to October)**	**Total**
Male	6	12	14	32
Female	2	4	8	14
Total	**8**	**16**	**22**	**46**

Discussion

Palau has 3 major live-aboard dive ships each able to offer 10 to 20 divers up to 5 dives per day. There are also approximately 10 shore based diving organisations which generally offer 2 dives per day diving from fast runabouts which take 90 minutes to reach the dive sites. During a typical week in the peak seasons in Palau, there would be about 2,400 dives logged (calculated from 10 divers in 10 boats doing 2 dives a day [1,400] and 30 divers doing 5 dives a day [1,050]). This figure may well be an underestimate. I believe the number of cases presented to Belau National Hospital is only the tip of the iceberg. The incidence of decompression illness is in the order of 0.1 % to 0.01%, which translates to 1:1,000 to 1:10,000 dives.[1-3] The 1996 Diver Alert Network (DAN) report deals with 1994 statistics when 1,164 cases of DCI were recorded.[4] DAN estimates of the number of active scuba divers is between 1,000,000 and 3,000,000[5] which gives comparable figures to those quoted above. Thus, in Palau one would expect to see 1 to 2 cases of decompression illness per week. However, the Palauan Hyperbaric Unit is treating only about 15 cases per year.

The breakdown of the citizenship of the patients with DCI treated in Palau (table 4) is also interesting. There is a discrepancy between the nationality of the patients treated with DCI and the distribution of tourist divers to Palau. Eighteen (39%) of the cases were US citizens, 7 (15%) were Japanese and 2 (4%) each from Palau, Hong Kong and the Philippines, in 9 cases (19.5%) the citizenship was not recorded. This distribution of cases is in contrast to the distribution of divers visiting Palau. Over 50% are either Japanese or Taiwanese tourists, but they only comprise 17% of the incidence of treated decompression illness in Palau. One can only assume that affected Asian divers were reluctant to present to the Palau Hospital for treatment because of language and social barriers. I hope that they do eventually seek treatment in their own countries, but I suspect this may not be the case.

The stress of completing an expensive diving vacation and connecting with international flights, may explain why many cases of DCI are not presenting in Palau. Divers often deny the possibility of DCI being the cause of their symptoms and mistrust of the foreign local medical facilities is common in tourists.

Decompression illness often requires multiple hyperbaric oxygen treatments, but the patients at Belau had an average of only 1.46 treatments. I suspect that many of the tourist patients deny residual symptoms in order to return home and that often these patients are not followed up when they get home. It is possible that some divers get inadequate treatment.

TABLE 4

CITIZENSHIP OF DIVING ACCIDENTS VICTIMS TREATED AT BELAU 1993 TO OCTOBER 1995

Citizenship	1993	1994	1995 (to October)	Total
USA	5	6	7	18
Unknown		1	8	9
Japan	1	4	2	7
Hong Kong		1	1	2
Palau		1	1	2
Philippines		1	1	2
France			1	1
Germany	1			1
India		1		1
Singapore	1			1
Taiwan		1		1
UK			1	1
Total	**8**	**16**	**22**	**46**

Chuuk State Hospital

After Palau, I spent a week at Chuuk State Hospital demonstrating and lecturing on aspects of anaesthesia and diving medicine. The Chuuk State Hospital is about twenty years old and serves a population of 60,000. In contrast to Palau, Saipan and Guam the conditions and standards in Chuuk were very primitive. During my visit, Chuuk State was in a financial crisis and the hospital was run down and there were severe shortages of medical supplies and equipment. The hospital survives solely on donated medical supplies.

Truk Lagoon is a Mecca for enthusiastic scuba divers who wish to explore the numerous sunken Japanese WWII wrecks. Most of the diving in Chuuk occurs in deep water and there are many repetitive and decompression dives performed. As a result, the DCI rate is much higher than normal. In Truk Lagoon there are two live-aboard diving boats offering up to 5 dives per day and 4 shore based diving organisations which generally provide 2 dives per day. These diving facilities generate approximately 1,000 dives per week and thus, assuming that the incidence of decompression illness is approximately 0.1%, the inference is that Chuuk will produce at least 1 case per week.

Unfortunately, the nearest recompression facility is in Guam, a two hour flight by commercial airlines. It is tragic that although the US Navy donated and installed a new multi-place recompression chamber at the Chuuk State Hospital in 1990 it has never been used. This is due to the lack of trained medical, technical and nursing staff to operate and maintain the unit. Another problem is a lack of adequate supplies of oxygen. There are no facilities available to fill cylinders with medical gases on the island, so oxygen is purchased, (at considerable cost), directly from Guam and unfortunately the deliveries are often unreliable.

When I inspected the recompression chamber, I noted that one of the compressors was not functioning and that a regulator in the built-in breathing system (BIBS) needed to be repaired. Otherwise, the hyperbaric system was in pristine condition. I suggested that a medical team from Chuuk should be sent for training in diving and hyperbaric medicine and the unit be repaired as soon as possible. The chamber would be financially profitable with the number of tourists requiring recompression treatment and in conjunction with the Diving Association of Chuuk, a diving levy could also be imposed to generate funds to maintain the facility. Volunteers from the diving tourist industry could also be recruited to be attendants for the chamber.

Micronesia is one of the best diving locations in the world but in certain parts of the region, as expected, the medical facilities are far below the standards that are found in Australia and New Zealand. The majority of tourists to Micronesia are Japanese, Taiwanese or American, but with the resumption of flights from Sydney to Guam by Continental Micronesia Airlines, there will be an increase of Australian divers visiting the area. Even now some of the Hyperbaric Units in Australia see divers who develop symptoms on the aircraft while flying home after a stint in Truk Lagoon.

When travelling to such areas for diving vacations, several guidelines should be followed. Dive conservatively, limit the number of repetitive dives, avoid decompression dives, do safety (decompression) stops, avoid deeper dives, do not mix alcohol with diving, do not fly until 24 hours after diving and have adequate travel insurance to cover medical emergencies, as the cost of treatment of diving accidents can be astronomical, should all be adopted as essential parts of a diving holiday. Finally, recreational diving is supposed to be for fun and most diving incidents are preventable so take care and enjoy the diving!

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DIVING DOCTOR'S DIARY

A DIABETIC DAMSEL IN DISTRESS

Carl Edmonds

This story is that of a qualified scuba diver who developed diabetes and required insulin.

Key Words

Diabetes, drugs, safety.

Case report

A 24-year-old was qualified as an open water diver in June 1994. She logged 40 dives after her course and was an enthusiastic and a capable diver.

She had no problems when diving until early in January 1996 when she felt nauseated and vomited soon after reaching depth. She vomited through the regulator and purged it afterwards. She then felt better and continued the dive.

Later that month, after a period in which she had not eaten very much, she was aware of a nervousness during a dive. This was very atypical for her. She was also aware of a dry throat, but the main problems were tremor and distress during a dive which she had completed uneventfully on previous occasions, and in conditions which were otherwise pleasant.

The depth was 12-15 m and there was no environmental or equipment cause for concern. She was aware of hyperventilation, but felt that this would settle after the dive was underway. It did not.

The descent had been feet-first and there was no history of air swallowing or middle ear problems. At depth she felt nauseated and vomited into her regulator. She took it out of her mouth and purged it. She refrained from any further exertion and informed her buddy that she needed to ascend. They did this and she vomited again while being assisted on board.

She was very distressed by the dive and the associated emotional sensations, but this did not prevent her from diving again that evening, uneventfully.

Following this diving incident, and because of it, she sought assistance a few days later, when the history of polyuria and polydipsia, associated with glycosuria, resulted in positive investigations for diabetes. Subsequently she was adequately controlled on isophane insulin (Protaphane) 6 units b.d. and neutral insulin (Actrapid) b.d., 2 units a.m. and 4 units p.m.

During stabilisation she was aware of occasional hypoglycaemic symptoms and signs, in the form of irritability, aggressive behaviour, shaking, paraesthesia and numbness, and a sensation of derealisation. She was not aware that hypoglycaemia could lead to unconsciousness and convulsions.

Now the only complications that she has from her diabetes are mild hypoglycaemic episodes, which are easily controlled.

She knew that there was disagreement in the diving medical fraternity about the safety of diving with diabetes.

Discussion

I explained to her that, as she had a perfectly valid open water certificate (C Card) I had no legal right to stop her from scuba diving. Nevertheless I strongly advised her against such an activity. I also stated that I would not consider her suitable for passing the Australian Standards 4005.1, which is normally required for scuba diver training.

I agreed with her about the importance of maintaining a good state of physical fitness, nutrition and the associated diabetic control.

HYPOGLYCAEMIA

The control of diabetes, in the scuba diving environment, is particularly difficult. This is partly due to the variable exertion that can be required, and often is required, to regain the safety of land or boat. When exertion is maximal this puts a great deal of strain on the insulin-glycogen-carbohydrate metabolism. Under these conditions there is an increased likelihood of hypoglycaemia.

The possibility of mild hypoglycaemic attacks producing atypical or fewer symptoms in the aquatic environment was also explained, together with the progression of this condition to unconsciousness and epileptic convulsions (and the probable fatal consequences of this, if it occurs underwater).

It would certainly be wise, if she were to insist upon scuba diving, to restrict it to extremely gentle environmental conditions that are not likely to cause any significant physical demands on her, i.e. diving in waters without current and with facilities to ensure no significant exertion.

Statistics on unselected insulin dependent diabetic divers are not available. A retrospective survey of survivors who continue diving, (always the best population to demonstrate "favourable" results) suggested that 15% had experienced hypoglycaemic episodes underwater.[1]

The diabetic diver is between the traditional rock and a hard place. The hypoglycaemic episodes, which are less likely to be recognised under water, will be induced by a situation in which the person is already at risk, swimming against a current in an attempt to return to safety. The energy requirements and glucose utilisation will be close to maximum. Hypoglycaemia will be far more likely, and the accident will be particularly difficult to cope with, both during the convulsive phase and the pre- and post-ictal confusional states.

KETO-ACIDOTIC REACTIONS

Most of these cases have been in experienced divers. Dr Peter Chapman-Smith presented a case of a diabetic physician/diver at the 1982 SPUMS Annual Scientific Meeting in Madang,[2] over a decade ago, although I am not sure if Peter (or anyone else) realised the significance of the case at the time.

The association of a diabetic syndrome (with acidotic state), dyspnoea and hyperventilation (with excessive air consumption), a confusional state and atypical (panic) behaviour, impressed both Peter and his buddy, as did the result.

The problem has also been referred to briefly in diving medical texts,[3] based on similar cases.

Some diabetics have continued diving but have found it necessary to suspend the pre-diving dose of insulin, to reduce the hypoglycaemic episodes. Unfortunately this is likely to predispose to the development of the keto-acidotic reactions, which this diver describes so very accurately in her "pre-diagnostic" dives (all my other cases were in established diabetics, so this lass posed a temporary diagnostic dilemma).

If insulin dosage is reduced to a significant degree, to ensure that adequate blood glucose levels are maintained despite the excessive metabolic demands, then the combination of insulin deficiency and glucagon excess is likely to increase the fatty acids and other ketones in the blood, cause a reduction of pH and the associated changes in potassium, sodium, magnesium and bicarbonate metabolism. Respiration is stimulated.

The resultant increased respirations are magnified in their psychological effect by the restrictions induced by excessive breathing through a demand valve. This will be especially so with increased depth, as the resistance to breathing increases.

The keto-acidotic episode, which is nowhere near that seen in the diabetic ketotic coma, can and does produce the episodes described above. It is unfair to dismiss these manifestations as merely a "near panic" or anxiety episode. That belittles the probable organic (biochemical) basis of the disorder.

In this case, the additional and possibly precipitating symptoms of anorexia, nausea and vomiting, preceded the more typical dyspnoeic complex and the emotional reaction/confusional states. The latter can occur in the most well-balanced, non-neurotic diabetics.

In this case, the relative effects of physical stress (a common precipitant of keto-acidosis), insufficient food intake and the vicious cycle of vomiting and dehydration, could well have had a less favourable outcome with less capable divers.

DECOMPRESSION SICKNESS

A warning was given regarding the increased risk of decompression sickness (DCS) with diabetes, and the need to reduce both the allowable bottom time and the maximum depths, with dive exposures. A suggestion (not based on any factual information) was made that reduction of the allowable bottom time by at least 50%, and diving to a maximum of 15 m, with a minimum surface interval of 6 hours, might reduce the risk of significant DCS.

In considering the explanations for the increased likelihood of DCS, the causes could be multiple. Possibly the dehydration associated with the diabetic state (especially after withheld insulin), hyperosmolarity, increase in blood viscosity, and increased thrombotic tendency, are all likely to increase the DCS syndrome.

Alternately, the already damaged walls of diabetic vessels might be a factor in the intravascular bubbles causing further pathology. This is all theoretical, but the results are not. It does seem as if diabetics, once they get DCS, get it with gusto.

OTHER PROBLEMS

I briefly mentioned autonomic neuropathy, cardiac sequelae and other problems associated with sea water exposure, including infections, and hoped that she would not pursue her intention to continue scuba diving.

The seminar, at the 1996 Undersea and Hyperbaric Medical Society Annual Scientific meeting, on diabetes and diving is, according to my information, likely to be no more informative than the one on asthma. So one is going to have to rely on common sense, a knowledge of diabetes and one's experience in diving medicine to advise patients. Extremely "soft" statistics, enthusiasm from protagonists and a desire to be avant-garde will also influence some medical advisers.

Others will use medical approval for motor vehicle driving as a corollary for diving, despite the vastly different demands of the two environments and the occasional case report showing that even driving for "controlled" insulin dependent drivers is sometimes lethal for them and their passengers.

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THE WORLD AS IT IS

CHAMBER FAILURE

Harry Oxer

Key Words

Fire, hyperbaric facilities, hyperbaric oxygen, treatment.

The incident

On February 25th 1996 at 1505 on the first floor of a hospital at Yamanishi, Japan, there was an event that rocked the hyperbaric units of the world. There had been an apparent explosion associated with a monoplace chamber, and the violent disruption killed two people, and seriously injured a third.

Professor Hideo Takahashi, president of the Japan Hyperbaric Society and Head of Hyperbaric Medicine at Ngoyo University, gave a special presentation on this tragic accident at the Undersea and Hyperbaric Medicine Society Scientific meeting, in Anchorage, Alaska, in June 1996. This is a report of that presentation.

A 74 year old man was undergoing hyperbaric treatment for the chronic results of a brain infarct. He was recovering slowly, but had expressed a keen desire to have hyperbaric oxygen with a view to accelerating his recovery, and had been accepted for hyperbaric oxygen therapy.

All the treatments in this unit are run by two clinical engineers", as they call the technician operators, under the supervision of one hyperbarically trained neurosurgeon. There were three monoplace chambers in the unit, a 1989 Kawasaki, a 1990 Seechrist, and a 1992 Seechrist.

At the time of the occurrence there were patients in two of the chambers There were two technician engineers running the chambers, and observing the patients. At the time of the problem nobody was looking at this particular patient as the clinical engineer caring for this patient was speaking to a visiting doctor at the door of the room. The other was caring for a second patient in another monoplace chamber in the same room. There was an explosion and the 74 year old male in the chamber was severely burned. A hatch blew off one end and killed his 70 year old wife instantly. One of the engineers received a fractured skull from a flying end plate and two other people were slightly injured.

There was no fire and the external fire extinguishers were not activated. There was evidence of an intense fire within the shell which was smoke blackened. The chamber failed in the way in which it was designed to fail. Both the safety relief valves had operated, and there was evidence of soot passing through them, but of course they could not accommodate an explosive force.

The oxygen supply ceased immediately with the explosion and there was no subsequent fire within the unit. The windows of the room were blown out, as were light partition walls, and the ceiling was disrupted.

The patient was 45 minutes into a treatment at 2.7 ATA on 100% oxygen.

Initially a statement was released that all recommended safety procedures had been fully carried out.

However this was subsequently found not to be so. A subsequent statement admitted that the patient was put into the chamber in his own clothes and that no body check or belongings check was done. He had been wrapped in the heavy acrylic blanket in which he had been brought from another hospital.

Investigations

A full investigation was undertaken. The police were involved. The Japanese Hyperbaric Medical Society was involved from the beginning and Seechrist had their own representative on site within 72 hours, but he was not allowed to get to the actual scene for several days. Seechrist, of their own volition, put out a letter to all Seechrist chamber operators advising that use should be suspended until they found out what the problem was. This was despite there being no indication that this was in fact a chamber failure.

The Japan Hyperbaric Medicine Society conducted their own investigation which looked at three aspects of the problem.

The medical indication

There are currently 21 disorders accepted by the Japan Hyperbaric Medicine Society, but chronic brain disorder is not one.

Supervision and observation

Neither of the technicians was actually observing the patient in the chamber at that time. The one who should have been was in fact distracted, facing the other way and speaking to a visiting doctor at the door of the room and also to the wife who was just outside the door. Therefore no signs were seen and nobody observed exactly what happened. However the patient intercom was on loudspeaker and no sound was heard from the patient calling for help or asking for anything. The first sign that anything was amiss was the explosion.

Ignition Source

The first cause that was suggested was static electricity. This was fairly quickly discounted. Many experiments have since been done and, though they had been able to generate static crackles, they were quite unable, under any pressure and oxygen concentration, to cause ignition of any of the substances such as the blanket, mattress, cotton materials, plastic materials or other things that had been within the chamber.

Suspicion fell on a personal heating device called a “Kairo”. They are extremely commonly used in Japan and widely available from supermarkets. They are spontaneous heating devices.

They can be bought either as a metal refillable pocket warmer or as a disposable “Kairo”. The latter can be bought under the trade name “Mr Hot”. They consist of a pouch of material rather like the material holding coffee for a filter coffee machine. The contents look like a black garden mulch. In fact the filling is a mixture of 50% iron filings (powered iron) 50% water with 7 g of activated charcoal, which contains a platinum catalyst, some vermiculite and some salts. This is sealed in a plastic packet to exclude air. If the seal is broken oxidation starts and generates a temperature of 50 to 60° C, slow warmth of up to 40 to 50° C, for up to eight hours. Some of these packages have sticky attachments so they can be stuck on to the clothes of the person, over an area needing warmth, or somewhere around the waist where the warmth is transmitted to the whole body. Placed next to the skin they can cause small burns.

Experiments have been done with “Kairos” in 2.7 bar of oxygen when they have successfully ignited materials similar to those that were in the chamber.

There have been reports of previous occasions when people have taken these into a chamber attached to their clothes. In the most recent one the patient complained of minor burns when the device became too hot quite rapidly. Oxygen and compression were discontinued and the patient was extracted satisfactorily.

In this case the patient did survive initially, but subsequently died of burns. Forensic examination confirmed traces of iron filings powder on some of the clothes of the patient which supports the suggestion that a “Kairo” was the probably cause of ignition.

Seechrist stated that previous fires have occurred from this cause and have been contained inside the chamber. This one was not so contained. Once a fire developed there would be a huge expansion of gases as they heated up, and a subsequent very rapid pressure rise, almost instantaneous.

How the chamber failed

The tie rods failed first and therefore the end caps came off but, because of the pressure, were projected a considerable distance. The flying entrance hatch hit the wife and killed her instantly. The flying cap, possibly from the other end, caused the skull fracture in one of the engineers. The other two people sustained minor injuries only.

The acrylic chamber cylinder survived the initial explosion, but was disrupted by falling when it was blown off its rest and was damaged by flying debris later. It was, however, still largely intact. The acrylic was blackened on the inside and both the exhaust valves had opened and passed the soot containing gas as planned, but of course they could not cope with the exhalation of the huge amount of gas of an explosion.

Seechrist chambers

The Chief Executive of Seechrist, David Bush, spoke and stated that they had over 700 chambers around the world that had been in use for 20 years. He said that no patient had ever previously been injured.

Seechrist were originally told there had been no fire, therefore initially sent a letter out advising stopping all use of their chambers because of the possibility that the hull had failed. They immediately contacted the Federal Drug Authority (FDA), who later complimented the firm on its responsible and professional approach to the whole thing.

It was quickly established that the chamber had failed in a manner in which it should. Seechrist chambers are constructed in accordance with the requirements of PVHO (Pressure Vessel for Human Occupancy) Division of the ASME (American Society Mechanical Engineers) standards for a chamber building. This requires that it should fail in such a way that the hull of the chamber does not explode or disrupt.

Since this incident, many people have tightened their procedures and have found errors. One patient was trying to get in complete with cigarettes and a lighter! Some units, particularly in Japan, are now trying to use metal detectors such as the portable ones used at airports. They would pick up the iron filings in a package such as the “Kairo”.

A few units have changed to compression with air, with oxygen breathing by mask or hood, but this demands meticulous attention to the mask or hood fit to control leakage and the oxygen percentage in the chamber. The Japan Hyperbaric Society, after its review, still recommends compressing all patients in oxygen in these chambers.

Seechrist pointed out that the very small number of other incidents that have occurred in their chambers have not resulted in patient injury and that each has been due to a different problem, none of which has been due to their equipment failing. There have been two or three abnormal events such as unexplained decompressions, though these were put down to inadvertent operator error when investigated.

This is the only major accident for this firm in 20 years with over 700 chambers in operation and with many millions of patient treatments.

There has never been a validated failure of a Seechrist chamber nor an injury resulting from a problem.

Conclusion

A full report will be put out shortly, probably in October. An abbreviated report will appear in the next edition of *Pressure*.

The meeting was given an extremely frank and very detailed verbal report. It illustrated, once again, that recompression of patients, within a hyperbaric facility, in a high oxygen concentration is not without risk. However, the Chief Executive Officer of Seechrist pointed out that any form of compression therapy runs the risk of decompression injury such as barotrauma, even though the risk is very small.

Dr Harry Oxer is Director of the Hyperbaric Medicine Unit at the Fremantle Hospital, PO Box 480, Fremantle, Western Australia 6160. Phone +61-9-431-2233. Fax +61-9-431-2819

A verbal report of this incident was presented at the Hyperbaric Technicians and Nurses Association (HTNA) Meeting in Hobart in August 1996.

MEDICAL CERTIFICATES AND NEW DIVING LEGISLATION IN QUEENSLAND

John Hodges

Key Words

Legal, medicals, medical standards, occupational diving.

Introduction

For the last six years, Queensland’s workplace health and safety legislation for underwater diving at a workplace required compliance with *AS 2299 - Occupational Diving.* This is no longer the case with new legislation which came into effect on 2 July 1996. The new legislation, the *Workplace Health and Safety (Underwater Diving Work) Compliance Standard 1996,* has specific requirements about certificates of medical fitness to dive for people doing any underwater diving work.

Who has to hold a medical certificate?

Employers, self-employed people and workers who do any type of underwater diving work must hold a current "certificate of medical fitness to dive". This applies across the board to all types of diving work, not to members of the public doing recreational diving or other non-work activities. Examples of underwater diving work include underwater filming for a movie, fish collecting, scrubbing the hull of a ship and training recreational divers.

While the compliance standard is effective from 2 July 1996, people doing the following types of underwater diving work are not required to hold a current "certificate of medical fitness to dive" until 2 July 1997:-

- people who conduct recreational diving or training to go recreational diving (for example, dive instructors and dive masters who conduct these activities as part of their employment)

- people who take souvenir photographs, films or videos of people doing recreational diving (for example, this covers a person who takes underwater photos of people doing recreational diving and sells those photos to the people doing the diving).

It is the responsibility of the employer to make sure his or her worker holds a current certificate of medical fitness to dive. Employers and self-employed people must also hold a current certificate if they are going to do any underwater diving work.

What is a current certificate?

A current certificate is one that is less than 12 months old and has not expired, been revoked or superseded. People doing underwater diving work will need to have an annual medical examination to obtain a "current" certificate.

A **"certificate of medical fitness to dive"** is a certificate that:

a is issued by a doctor who has satisfactorily completed training in diving medicine approved by the Board of Censors of the South Pacific Underwater Medicine Society; and

b contains the following information:
- the name of the person who holds the certificate;
- the date the certificate was issued;
- shows that the person is medically fit to dive according to the fitness criteria in AS 2299-1992 *Occupational Diving*, appendix A, paragraph A3;
- any limitations on diving imposed by the doctor.

If the person is under the age of 18, the doctor may issue a certificate despite the minimum age of 18 for a diver being stated in AS 2299 - 1992, appendix A, paragraph A3. However, the certificate must show either:

- that apart from being under 18, the person is medically fit to dive in accordance with AS 2299 - 1992, appendix A, paragraph A3 and no limitations on diving are needed even though the person is under 18; or

- that apart from the limitations on diving stated on the certificate, the person is medically fit to dive in accordance with AS 2299 -1992, appendix A, paragraph A3. The certificate must show which, if any, of the limitations are imposed because the person is under 18.

While the AS 2299-1992 fitness criteria specify a minimum age of 18 for divers, the compliance standard allows people under the age of 18 to hold a certificate of medical fitness to dive as there are circumstances where a person under the age of 18 may wish to do underwater diving work. For example, a 16 year old actor may be required to do underwater diving scenes for a film and therefore would need to hold a certificate of medical fitness to dive. Whether a person under 18 is declared fit to dive or not is a matter for the doctor's discretion. The type of diving work the person intends to do may be a relevant factor in assessing whether the person is fit to dive.

As employers, self-employed people and workers doing underwater diving work in Queensland must hold a certificate that shows the above information, it would be most useful if doctors issuing certificates to these people make sure all the relevant information is shown on the certificate.

Training in diving medicine

The compliance standard requires the certificate to be issued by a doctor who has satisfactorily completed training in diving medicine approved by the Board of Censors of the South Pacific Underwater Medicine Society (SPUMS). This is more specific than previous legislation which did not make an explicit statement about the experience in underwater medicine a doctor required to issue a diving medical certificate.

At present, doctors who have satisfactorily completed any of the following training may issue a certificate of medical fitness to dive:

Royal Adelaide Hospital Basic Course in Diving Medicine and the Advanced Course in Diving and Hyperbaric Medicine

Royal Australian Navy Basic Course, Advanced Course or the Medical Officers Underwater Medicine Course

Diving Medical Centre Medical Examiner Course
Fremantle Hospital Medical Assessment of Divers Course
Royal New Zealand Navy Basic Course
Christchurch Hospital Basic Course
Institute of Naval Medicine (UK) Medical Examiner Course
United States Navy Diving Medical Officer Course

If the Board of Censors of SPUMS approves any new training in diving medicine, these courses will also be covered by the compliance standard.

Because SPUMS recommends courses of 10 days duration or more as the most appropriate training for carrying out AS 2299-1992 medical examinations, it needs to be noted that the compliance standard permits a doctor with any training in underwater medicine approved by the Board of Censors to issue certificates of medical fitness to dive, and that not all approved courses meet the recommended training period of 10 days.

Brochures about diving medicals and construction diving work are available from the Division of Workplace Health and Safety.

Copies of workplace health and safety legislation can be ordered through the Division or from GOPRINT (telephone 07 3246 3399 or facsimile 07 3246 3534). The Division of Workplace Health and Safety is now on-line. Workplace health and safety legislation can be accessed on the Division's homepage via the Internet. Home page address http://www.gil.com.au/va/whs-home/whs/htm .

J E Hodges is Executive Director, Division of Workplace Health and Safety, Department of Training and Industrial Relations, Queensland. Enquiries about the legislation should be directed to Carmen Langan, Research Officer, Planning and Program Development Branch, Division of Workplace Health and Safety, Department of Training and Industrial Relations, GPO Box 69, Brisbane, Queensland 4001, Australia. Phone 07-3247-5671. Fax 07-3247-4519.

SPUMS NOTICES

CORRECTIONS TO SPUMS JOURNAL SEPTEMBER 1996

A REVIEW OF THE SHARPENED ROMBERG TEST IN DIVING MEDICINE

Ben Fitzgerald

SPUMS J 1996; 26 (3): 142-146

On page 144 Table 4 was missing some results. The corrected Table 4 is printed below.

TABLE 4

SHARPENED ROMBERG TEST SCORE IN DIVING PATIENTS WITH AN ABNORMAL RESULT (LESS THAN 30 SECONDS) BEFORE HYPERBARIC TREATMENT (HBO) AND AT DISCHARGE.

	Number	Pre-HBO Best [mean]	Pre-HBO Best [S D]	Discharge Best [mean]	Discharge Best [S D]
Total	17	5.94	7.93	50.88	18.01
20-40 years	9	8.11	9.31	57.56	7.33
Over 40 years	8	3.50	5.66	43.38	23.62

On page 145, right hand column, paragraph 2, there is mention of Appendix B. This is an editing error which occurred when Appendices A and B were included in the text.

Since publication of this paper Dr Fitzgerald has moved to 5/47 Bramston Terrace, Herston, Queensland 4006, Australia.

NITROX
David Elliott
SPUMS J 1996; 26 (3): 194-198

On page 198 Reference 5 is incorrect. It should read

5 Hamilton RW. The scope of non-conventional recreational diving. SPUMS J 1996; 26 (3): 191-194

BUOYANCY
SPUMS J 1996; 26 (3): 208-209

This paper was written by Keith Waugh, whose name was most unfortunately ommited.

Key Words
Corrections.

ACKNOWLEDGMENTS

The Editor wishes to acknowledge and thank those who have helped keep the Journal on the "straight and narrow" over the last few years.

Editorial Assistants (Proof readers)

Drs John Couper-Smartt and David Davies.

Without their help the Journal would have contained many more typographical and English usage errors than it has.

Peer Reviewers

Drs David Davies, Mike Davis, Carl Edmonds, Bill Hurst, Douglas Walker, John Williamson, Rick Wolfe and Mr Justice Tom Wodak.

MINUTES OF THE SPUMS EXECUTIVE TELECONFERENCE
held on Sunday 28 July 1996

Opened at 1000 Eastern Standard Time

Present

Drs G Williams (President), C Meehan (Secretary), R Walker (Treasurer), J Knight (Editor), D Davies (Education Officer), M Davis (NZ Chairperson), V Haller and M Kluger (Committee members).

Apologies

Drs C Acott (Committee member) and D Gorman (Past-President).

1 Minutes of the previous meeting (21/4/96)

Read and accepted as a true record after minor changes. Proposed J Knight, seconded R Walker.

2 Matters arising from the minutes

2.1 North American Chapter update. Dr Walker to investigate.

2.2 Maldives conference expenses registration account update. There was one registration fee still outstanding. It was suggested that one account only remain open with the remnants of the conference monies from Fiji and the Maldives. It was proposed that SPUMS should consider purchasing a projector for direct computer presentation in the future.

2.3 New Zealand 1997 ASM update. All going well at this stage. As this is an onshore conference, some commercial sponsorship is to be sought. Dr Davis will do this in New Zealand and Dr Williams in Australia.

2.4 Indemnity policy update. This is still being looked into by Dr Williams.

2.5 Reprinting of the schedules for SPUMS Diving Medical and Statements of Purposes and Rules. Secretary to make sure that the amendments to the AS 4005.1 are incorporated with regard to chronic illness. Progress is being made with this.

2.6 Role of convenor to be defined and guidelines written. These should now be available from Dr Acott.

2.7 Ex-Presidents Committee. The Secretary and Treasurer will need a list of the members of this committee. The committee needs to be notified of the face to face meeting which will be held in Melbourne in October. Dr Gorman will co-ordinate with the members of this committee and arrange a meeting at this time if he so wishes.

2.8 Subscription Renewal Notice to be redesigned. This is to be finalised at the next committee meeting in Melbourne.

2.9 Diving Doctors List update. The Diving Doctors List is in the process of being formatted by Steve Goble at the Hyperbaric Medicine Unit, Royal Adelaide Hospital. There will be an asterisk beside all doctors who have completed a course of 10 or more days duration. At present three courses fulfil this criterion. They are the Royal Adelaide Hospital Basic plus Advanced

Course, the Royal Australian Navy Medical Officers Underwater Medicine Course and the United States Navy Diving Medical Officers Course. The next list should be produced in December. A new form needs to be designed for next year which allows for recognition of these courses.

2.10 Update on the Index of the SPUMS Journal being produced on a disk. There has been a problem getting this into Access. This is being looked into.

3 Treasurer's report

Dr Walker presented an interim report.

4 Correspondence

4.1 Letter from Dr Brian Hills. Dr Knight has written to Dr Hills with reference to the 1997 ASM in New Zealand.

4.2 Letter from PADI Solicitors re: article in the Brisbane Sunday Mail, 26 May 1996. Acknowledgment of receipt of this letter has been sent.

4.3 Letter from Dr Finlay-Jones, 26/7/96. Letter has been acknowledged .

5 Other Business

5.1 Next committee meeting will be in Melbourne on the 19 October. As Dr Gorman will be in Adelaide from 21 Oct to 1 Nov 96, it was suggested that he may stop in Melbourne on route. At this time, Melbourne is an easier and cheaper destination for most members. Dr Gorman will arrange for the Ex-Presidents Committee to meet at the same time if he so wishes.

5.2 Future ASM venues. It was suggested that the 1998 ASM be held in Palau and that the 1999 ASM be held in Langang. It was proposed that the convenor and the co-convenor be responsible for deciding which travel provider to use.

5.3 Oxygen equipment for dive boats at ASM. There was some discussion. One suggestion was that this be hired as needed, as some venues would have adequate equipment available. This is to be further discussed in Melbourne.

5.4 Suggested change in packaging of the journal. To be further discussed in Melbourne.

5.5 Upgrade of computer for the Editor was agreed. He is to liaise with the Treasurer on this.

5.6 Scanner for Secretary was approved. The Treasurer requested that every committee member bring a list of all the SPUMS equipment and furnishings held to the next meeting so an inventory can be maintained.

5.7 Draft of policy statement on technical diving. To be circulated.

5.8 SPUMS European representative. It was suggested that SPUMS should have an European representative. Some discussion was entered into and this will be further discussed in Melbourne.

5.9 SPUMS e-mail, home page and the web. SPUMS Secretary's home page can be read on :http:/ www.ozemail.com.au/~cmeehan/index.html. Further discussion is expected re SPUMS and the internet.

5.10 Request for temporary financial assistance for the Diving Emergency Service. A letter was read from Dr Acott with regard to this. After some discussion, this matter was left for fuller attention at the Melbourne meeting. Moved that funding of the costs of running DES for the next three months be made by SPUMS as an interim measure. Proposed Dr Williams, seconded Dr Knight. Carried.

5.11 Workplace Health and Safety, Queensland requested SPUMS' opinion of terminology "exercise ECG" as used in AS 2299. This was unanimously agreed to mean a full stress ECG.

5.12 Medis equipment disinfectant. Dr Knight stated that he had received a letter suggesting an editorial in support of their product. He stated that even if they had provided some evidence of effectiveness of the product, which they did not, Journal policy was completely opposed to such departures from scientific standards. Nothing further has been heard from the company.

Closed at 1200.

24th ANNUAL SCIENTIFIC MEETING AND ANNUAL GENERAL MEETING
12th to 20th APRIL 1997
at the
QUALITY RESORT WAITANGI,
BAY OF ISLANDS, NORTHLAND,
NEW ZEALAND

Theme
PATHOPHYSIOLOGY AND TREATMENT OF DECOMPRESSION ILLNESS

SPUMS Workshop
FIRST AID MANAGEMENT OF DIVING ACCIDENTS

Guest Speakers

Professor Richard Moon, Duke University, Durham, North Carolina, U.S.A., Immediate Past President, Undersea and Hyperbaric Medical Society.

Dr James Francis, until recently Director, Naval Medical Institute, Alverstoke, United Kingdom.

Richard and James are acknowledged as among the world's leaders in decompression illness. Both were major contributors to the 4th edition of *The Physiology and Medicine of Diving* edited by Peter Bennett and David Elliott. Richard Moon is also the Medical Director of DAN (Diver Alert Network) International. This meeting gives SPUMS members an opportunity to hear two outstanding international speakers.

Conference Convenors
Dr Michael Davis and Associate Professor Des Gorman

For further information contact:
Dr Michael Davis
Hyperbaric Medicine Unit , Christchurch Hospital
Private Bag 4710, Christchurch, New Zealand.
Fax +64 3 364 0187. e-mail at hbu@smtpgate.chhlth.govt.nz

Diving Workshops

The diving at The Poor Knights Islands is considered to be amongst the finest temperate water diving in the world. Water temperatures will be about 20°C.

Delegates will travel to the Poor Knights Islands on 3 days on board a large high-speed catamaran, Tiger IV, which can carry around 250 passengers. During the journeys small group workshops, equipment demonstrations and hands-on training sessions related to the workshop theme of the First Aid Management of Diving Accidents will be conducted.

Conference Week Activities

This is a beautiful maritime park region of New Zealand, which is also an area of considerable historical importance. For the non-diver, there is a wealth of land and water-based activities with something for everyone.

The Quality Resort Waitangi is an ideal family venue. A diverse and exciting children's programme has already been developed to suit all ages, as well as excellent baby care facilities.

Bring the whole family for a wonderful New Zealand Holiday!!

Pre- and Post-Conference Tours

Two contrasting and outstanding diving venues will be offered. The Three Kings Islands, situated some 30 miles North of New Zealand, and Fiordland, on the West Coast of South Island.

In addition, self skippered sailing charters at very competitive rates have been reserved and there is an immense range of other holiday opportunities in New Zealand that Fullers Northland's travel division will be able to advise delegates on.

For all travel and New Zealand domestic enquiries, please contact:
Fullers Northland (attention Tania Townsend)
PO Box 145, Paihia, Bay of Islands, New Zealand.
Phone +64 9 402 8802 Fax +64 9 402 7831

PLEASE HELP US TO MAKE THIS A GREAT MEETING BY RETURNING THE REGISTRATION FORM ENCLOSED WITH THE LAST JOURNAL.

SOUTH PACIFIC UNDERWATER MEDICINE SOCIETY

DIPLOMA OF DIVING AND HYPERBARIC MEDICINE.

Requirements for candidates

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

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

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

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

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

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

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

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

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

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

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

THE 1997 ANNUAL GENERAL MEETING OF SPUMS

will be held at 1200 on Saturday 19/4/97 at the Quality Resort Waitangi, Bay of Islands, New Zealand

The following motions to be moved at the Annual General Meeting have been received by the Secretary.

From the Committee

That Dr David Elliott be elected a Life Member.

That Rule 3 Life Members, (b) be altered by replacing the word *five* in the last sentence by the word *eight*.

The new sentence would read: *The number of life members shall at no time exceed eight nor shall more than one such member be elected in the one financial year.*

From Dr Jim Marwood

That Rule 8 Annual General Meeting, (e) be altered by removing the words *of which notice has been given*.

The new rule would read: *The annual general meeting may transact special business in accordance with these rules*.

That Rule 11 Order of business at general meetings, (a) be altered by adding a new sub-section *(x) Any other business*.

That rule 12 Notice of meetings, (b) be altered by replacing the second *the* by *a special meeting*.

The new rule would read: *No business other than that set out in the notice convening a special meeting shall be transacted at the meeting*.

HYPERBARIC MEDICINE UNIT FREMANTLE HOSPITAL

MEDICAL ASSESSMENT OF FITNESS TO DIVE COURSE

March 14th-16th 1997

COMMERCIAL DIVE SUPERVISORS ADVANCED FIRST AID COURSE

73February 3rd-7th 1997

For further details contact

Dr Harry Oxer
Director Hyperbaric Medicine Unit
Fremantle Hospital

Tel (09)-431-2233
Fax (09-431-2918

LETTERS TO THE EDITOR

DIVING FOR THE DISABLED

8 Sloane Street
Hobart
Tasmania 7004
5 September 1996

Dear Editor

It suits the current American fashion for political correctness to imply that "disabled" has no more significance than "black-skinned" or "Protestant". This idea does have its advantages, but it has to be questioned when applied to our interest, that of keeping the risks associated with diving to a minimum

I draw your attention to series of papers on training people with disabilities in a recent PADI journal (*The Undersea Journal*, 2nd quarter 1996).[1-4] Now this is a laudable enterprise, and PADI is to be commended for promoting it. But I question some of the conclusions and recommendations in this series of articles.

The theme of the PADI statement of policy (this is what the journal amounts to) is that disabled divers, even some quite profoundly disabled, should be given every expectation not only of obtaining a basic open-water ticket, but of going on to "Advanced" and even "Rescue" qualifications.

This all implies that disabled candidates shall have passed a full dive-medical examination and poses serious questions about the philosophy behind the examination. Just what is it that we are saying when we sign the piece of paper that the student will carry to the instructor?

There are the two very basic factors that Des Gorman stresses during his dive-medical classes: will the conditions be made worse by diving and will the condition increase the risk of diving to an unacceptable level? Clearly any disabled diver must be able to answer no to both of these, but there is a corollary to the second, one rather harder to assess.

When I visit an unfamiliar dive site and board a boat, I show a card to the operator and I am paired with someone I have never met, also carrying a card. There follows a brief familiarisation with his (or hopefully, her) equipment. Then we leap into the ocean, each with some confidence that, should we get into difficulties, the other will give us a hand and, *in extremis*, will at least have a go at saving our life.

Clearly a paraplegic, a double amputee or an intellectually handicapped diver is most unlikely to be able to offer the expected assistance, yet the PADI policy would have him or her showing the dive operator the same qualification as everyone else and entitled to claim the same facilities. The operator is then left with the invidious decision to accommodate the disabled or risk a charge of discrimination (which is not as far-fetched as it may seem).

Let us be positive about this. The industry needs to remain rational while encouraging diving among disabled people. I have dived with amputees, with a paraplegic and with a young man with intellectual disability. I testify to the enormous boost the activity can give to self-confidence and self-esteem of the disabled. But it is necessary to temper political correctness with reality. Disabled means just that, someone who is in some respect less able. Diving may be adapted to special needs. The PADI Journal gives useful advice about this. But a disabled person is unlikely to give a positive answer to the corollary to Des Gorman's second question, that is "will the condition increase risk to the diver's partner? (Yes, all right, I know PADI calls them 'Buddy".)

It is my belief that a new qualification is needed, starting with medical assessment, continuing with special emphasis on individual needs; exit and entry techniques, buoyancy skills and so on. Qualification would be recognised with, perhaps, a D card. This card would permit the holder to dive with a divemaster, or accompanied by two well-informed and practised companions, but not to act as conventional 'buddy' (awful, un-Australian word). Clearly this suggestion runs closely parallel to the ideas put forward in connection with diabetes in the June SPUMS Journal.[5]

I suggest the theme "Diving for the Disabled" would make a most worthwhile subject for a SPUMS Annual Scientific Meeting in the near future. I am sure all the diving organisations, and not just PADI, would make contributions, and the subject should interest a number of specialists in rehabilitation who do not usually have contact with SPUMS.

Jim Marwood

References

1 Richardson D. Editorial. *Undersea J* 1996; second quarter: 3-4
2 Shreeves JT. Accommodating -not compromising. *Undersea J* 1996; second quarter: 5-7
3 Parry M. Scuba diving for people with disabilities. *Undersea J* 1996; second quarter: 8-9
4 Hemsworth G. Training divers with disabilities. *Undersea J* 1996; second quarter: 28-29
5 Lerch J, Lutrop C and Thurn U. Diabetes and diving: can the risk of hypoglycaemia be banned. *SPUMS J* 1996; 26 (2): 62

Key Words
Disabled, training.

This letter was sent to Drew Richardsibm PADI International Vice-President, Training, Education and Memberships, whose reply is printed below.

PADI International
1251 East Dyer Road #100
Santa Ana
California 92705-5605

8/10/96

Dear Editor

I read Dr Marwood's letter with interest, and while I agree that some of the issues he raises are valid, I disagree with what he implies, that there is something wrong when individuals who have physical or intellectual disabilities earn the same diver credentials as an individual without those disabilities. With all respect to Dr Marwood, it appears he may have missed the point while reading the 2nd Quarter 1996 *Undersea Journal*.

PADI's philosophy is that only those who meet the performance requirements of a particular course earns the certification. The performance requirements say nothing about the individual's characteristics, but rather, what the individual must be able to do. There are individuals with *and without* disabilities who fail to meet the performance requirements. These individuals do not earn, and do not receive, the certification.

This is not to say that there are not challenges in learning for individuals with some disabilities, but people without disabilities have learning challenges too. Instructional theory prescribes handling challenges by changing the instructional and learning components, *not* the individual

To handle some disabilities, adaptive or unusual techniques may be needed, to meet the performance. Mask clearing can be done by holding the top, by turning to the side and holding the edge, by purge valve and with two hands. If the mask ends up free of water in all cases, the method is right.

The idea that some divers with a particular certification will not be "equal" to other divers is not an issue, either. If a diver swims with his hands, it may be that he could not handle a current as well as another diver. However, the same could be said about an athlete diver and a more sedate diver. Individuals have personal limitations within qualifications and must use good judgement to stay within their limits. This is true for any diver, at any level, with or without physical or intellectual challenges.

Dr Marwood writes, "The theme of the PADI statement of policy ... is that disabled divers, even some quite profoundly disabled, should be given every expectation not only of obtaining a basic open-water ticket [sic], but going on to "Advanced" and even "Rescue" qualifications."

Dr Marwood is correct that this is our theme. The issue is what the individual can do, not what he cannot do. Achieving performance standards often rests with the determination of the individual with the disability, who may excel beyond all expectations, and exceed the performance of a normal person.

Dr Marwood may be correct to suggest that it is unreasonable to give individuals in such a situation "every expectation" of success, but the student, and no one else, decides what can be achieved.

Dr Marwood's concern about an individual earning a Rescue Diver certification, for example, would be groundless. If an individual can perform the skills, the diver earns the certification. He is as competent as any other PADI trained diver.

There are individuals, with and without disabilities, who fail to meet the medical requirements for diving. These people are not admitted into PADI programs. In the absence of medical contraindications to diving the training and educational process is the best way to assess an individual's ability to dive.

Dr Marwood also suggests a "special" certification for divers with individual needs. Groups such as the Handicapped Scuba Association, issue special certifications for individuals with disabilities who cannot meet the performance requirements for regular certification. These specialised certifications do identify the necessary qualifications for the buddy and even that there must be two able bodied buddies who can assist each other as well as the diver. So to this extent, Dr Marwood's suggestion stands.

Finally, PADI would support a SPUMS meeting that addresses diving for those who have physical and intellectual disabilities. We would hope the dive community at large would participate, and we would encourage everyone, including our competitors, to attend. However, we would prefer the title "Diving for those with Disabilities." To our way of thinking, there is a significant difference between having a disability, a physical or intellectual challenge, and being disabled.

Drew Richardson
Vice-President, Training, Education and Memberships

Key Words
Disabled, training.

BOOK REVIEWS

HYPERBARIC MEDICINE PROCEDURES

Eric Kindwall and Robert Goldmann

Published by St. Luke's Medical Center, 2900 West Oklahoma Avenue, Milwaukee, Wisconsin 53201-2901, U.S.A. 1995.

Key Words

Hyperbaric oxygen, procedures, treatment.

This is the seventh revision and update of the procedures manual that started life in 1970 as a loose leaf folder in the Hyperbaric Medicine Unit of the St Luke's Medical Centre. This publication is a credit to its authors and its establishment. It is not the sort of book that will be a million seller and destined for every bookshelf in the land but it certainly has a place in the library of every hyperbaric unit and on the shelves of any physician who is, in any way, involved in the management of hyperbaric patients.

In the six years since the last revision of this book, hyperbaric medicine has developed significantly and has matured. Its indications for treatment now have a much more scientific basis. Under pressure from the medical insurance organisations in the United States, the Undersea and Hyperbaric Medicine Society has instituted intensive reviews of all the indications for the use of hyperbaric therapy and all these accepted indications are covered comprehensively in this book.

After an introductory chapter on the role of HBO, its mechanisms and physiological effects, the authors spend the next 140 pages describing the day to day running of a chamber covering such topics as patient evaluation, patient care during therapy, wound care, pain and anxiety management, hazards and complications and oxygen toxicity. The third part of this section discusses the technical side of chamber operations, documentation, the role of the nursing staff, safety for the attendants, staff training and the differences in operating procedures for monoplace and multiplace chambers.

The remainder of the book covers, in more detail, each of the accepted indications for HBO. It gives a succinct review of the latest information on each condition that has been accepted as an indication for HBO therapy. It then suggests an acceptable treatment protocol and a brief review of the results. Each chapter has a short list of appropriate recent references to help with further investigation if needed.

Most hyperbaric units, and many hyperbaric physicians, already have a similar compendium of indications and protocols for treatment. The Unit at Fremantle certainly does and it is interesting to compare the protocols used with those of other similar units and see how they match up. By then comparing results we can estimate if we are heading in the right direction or not, and if not, how we should alter course.

This book will make a convenient reference for those practitioners undertaking the advanced course in hyperbaric and diving medicine provided that they understand that the treatment protocols suggested are not engraved in stone and may be altered in the light of local experience. It is easy to read, compact and well set out. Worth the money.

David Davies

SORT of DIVER. A Sport Diving Lampoon.

Published by Sort of Diver, Inc., PO Box 290083, Davie, Florida 33329-0083, USA.
Price $US 14.95 plus $US 1.50 for postage and handling.

This book should be on the table in whichever room you spend most of your time. It is a must for all those who read the usual diving magazines. Although its format is very similar, down to the flipping over many pages to find the continuation of the article, its contents are amusing and very often hilarious.

It would be unfair for me to discuss the contents too deeply. I think my favourite advert is that for the DSSD (Deep Sea School of Die-ving) with its heading REAL MEN DON'T JUST DIVE. The one for the World's Longest Lasting Mask Defogger comes close. The front cover with the picture (a magnificent shot of a startling event) and the caption *Has Fish-Feeding GONE TOO FAR?* triggers the thought "I must look inside".

Once you start flipping the pages you will find the usual sagas of magnificent diving holidays, but with a difference. There are advertisements for such useful items as the BENDS-FREE which enables you to dive deeper and longer in complete safety. Among the useful snippets is a puff for Decompression Airlines whose aircraft are pressurised according to the divers' personal dive profiles. Just the airline for SPUMS to use for the 1998 conference in Palau. Or is it?

The views expressed in this review are not those of SPUMS. They are the personal idiosyncrasies of the reviewer and his sense of humour. To quote from page 19, *STURGEON GENERAL'S WARNING. Reading Sort of Diver or attempting to dive using any of the products or methods depicted here in may cause bends, embolism, sinus squeeze or certain death.* The S-G should have warned of the risk of laughing fit to burst!

John Knight

SPUMS ANNUAL SCIENTIFIC MEETING 1995

MEDICAL ASPECTS OF SPORTS DIVING

A A Bove

Key Words

Air embolism, asthma, decompression illness, ENT, fitness to dive, flying and diving, pulmonary barotrauma, recreational diving.

Although the title is Medical Aspects of Sports Diving, cardiovascular problems,[1] diabetes and asthma will be passed over rapidly because they have been dealt with in other papers.

Pressure

Why do we discuss pressure in diving medicine? Because divers immerse themselves in water and change the ambient pressure by going up and down. There are a number of different ways to express pressure. There are pounds to the square inch (psi), millimetres of mercury (mm Hg or torr), feet and metres of sea water (fsw and msw), pascals (Pa), kilopascals (kPa) and megapascals (MPa), atmospheres (atm) and atmospheres absolute (ATA) and the other absolute measure, bar. There is plenty of scope for confusion. Table 1 (page 248) is the pressure conversion table published in every issue of Undersea and Hyperbaric Medicine. Descent increases ambient pressure and coming to the surface reduces it. These two changes generate most of the problems in diving medicine. The other major problem in diving medicine is the concern for physical activity.

Pressure drops as one goes to altitude. Whenever one moves from a higher to a lower pressure, some tissues are going to supersaturate. Things get worse going above sea level in an aeroplane after diving, as the tissue overpressures at altitude can be large enough to cause bubble formation when bubbles would not be formed if one had stayed at sea level. Most commercial aircraft are pressurised to the equivalent of 8,000 feet, about three quarters of an atmosphere. Eighteen thousand feet is exactly half an atmosphere. Sixteen thousand feet is 0.45 atm. Small unpressurised aircraft normally fly at around ten to twelve thousand feet. Some of them can go to 16,000 or 17,000 feet. Pilots in some of the better twin engine unpressurised aircraft, which can fly at 18,000 to 20,000 feet, can develop decompression sickness (DCS), without diving before flying, because they have reached a pressure which induces bubble formation in someone saturated at sea level.

Boyle's law is the cause of most diving problems. Ears are the most common problem. A good ear squeeze (aural barotrauma) early in the week will ruin the week's diving. Table 2 (page 249) shows the change of volume as a percentage for each 3 m (10 ft) as one descends in sea water from the surface to 30 m (100 ft). Going from the surface to 3 m (10 ft) there is a 32-33% reduction in volume. From 3 to 6 m (10 to 20 ft) there is a 20% reduction, from 6-9 m (20 to 30 ft) there is about a 13% reduction. Volume continues to shrink and a 3 m (10 ft) excursion from 27 to 30 m (90 to 100 ft) only produces a 2% change in volume. Why is this important? It is important because every now and then someone comes to me and says "My family doctor told me it is OK to dive as long as I don't go below thirty feet". When a physician says "Do not dive below 9 m (30 ft)" it is obvious that the doctor does not know about diving medicine, because this is the most dangerous area for barotrauma. The volume changes are largest and occur most rapidly between the surface and 9 m. It is very easy to get barotrauma effects in this zone. Below 10 m (33 ft) the volume changes are smaller per metre of depth change. Then it is easier to clear one's ears and much easier to control your buoyancy.

Ears

The tympanic membrane likes to have equal pressure on both sides. It requires effort to get ambient pressure into the middle ear. If the middle ear is not at ambient pressure the tympanic membrane will deflect and may ultimately tear. If one has difficulty equalising the middle ear, this means that there is a negative pressure in the middle ear with a differential not only between the outside water across the tympanic membrane but also between the middle ear and the perilymph (around the cochlea), the endolymph (in the cochlea and vestibular apparatus), and the spinal fluid, all of which are at ambient pressure, across the inner ear windows. The Eustachian tube closes at around 0.6 m (2 ft) of pressure differential and will not open. A forceful Valsalva manoeuvre trying to clear the ears can blow out the round window, causing an inner ear fistula damaging both vestibular and auditory apparatus. So, if one is having trouble equalising on the way down, it is not appropriate to keep going down doing increasingly forceful Valsalva manoeuvres.

Spinal cord

The spinal cord is the common site for injury due to decompression sickness in sport diving and is the common site for injury for bounce diving with air, to below 45 m (150 ft) for short times. James Francis[2] showed that there is a certain amount of supersaturation in cord lipids, and

TABLE 1

PRESSURE CONVERSION TABLE

The units of pressure preferred for manuscripts submitted to the *Undersea & Hyperbaric Medicine* are the pascal (Pa = Newton x m-2), kilopascal (kPa), or megapascal (MPa), defined by the International System of Units (SI). If the nature of the subject matter makes it appropriate to use non-SI units, such as fsw, msw, atm or bar, a parenthetical conversion to pascals, kilopascals, or megapascals should accompany the first mention of a pressure value in the abstract and in the text.

Atmospheres absolute is a modified unit of pressure due to the appendage “absolute”; the symbol “atm abs” is preferred over “ATA” for the modified unit.

1 atm	=	1.013250 bar	1 atm	=	33.08 fsw	1 atm	=	10.13 msw
1 atm	=	101.3250 kPa	1 bar	=	32.646 fsw[b,d]	1 bar	=	10.00 msw
1 atm	=	101.3250 kPa	1 bar	=	32.646 fsw[b,d]	1 bar	=	10.00 msw
1 atm	=	14.6959 psi	1 fsw	=	3.063 kPa	1 msw	=	10.000 kPa[c,d]
1 atm	=	760.00 torr[a]	1 fsw	=	22.98 torr	1 msw	=	1.450 psi
1 bar	=	100.000 kPa	1 psi	=	2.251 fsw	1 msw	=	75.01 torr
1 bar	=	100,000 Pa[a]						
1 bar	=	14.50377 psi						
1 bar	=	750,064 torr						
1 MPa	=	10.000 bar						
1 psi	=	6,894.76 Pa[a]						
1 psi	=	51.7151 torr						
1 torr	=	133.322 Pa[a]						

[a] Signifies a primary definition[1] from which the other equalities were derived.

[b] Primary definition for fsw; assumes a density for sea water of 1.02480 at 4°C (the value often used for depth gauge calibration).

[c] Primary definition for msw; assumes a density for seawater of 1.01972 at 4°C.

[d] These primary definitions for fsw and msw are arbitrary since the pressure below a column of seawater depends on the density of the water, which varies from point to point in the ocean. These two definitions are consistent with each other if a density correction is applied. Units of fsw and msw should not be used to express partial pressures and should not be used when the nature of the subject matter requires precise evaluation of pressure; in these cases investigators should carefully ascertain how their pressure-measuring devices are calibrated in terms of a reliable standard, and pressures should be reported in pascals, kilopascals. or megapascals.

Reference

1 *Standard Practice for Use of the International System of Units (SI). Document E380-89a*. American Society for Testing and Materials. Philadelphia, Pennsylvania, 1989.

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probably brain lipids as well, which is associated with nitrogen uptake in that kind of a profile. He dived dogs, in a chamber, for four hours at different depths, 6 m (20 ft), 12 m (40 ft), 18 m (60 ft), 24 m (80 ft), 30 m (100 ft) and so on, then decompressed and sacrificed them to study the spinal cord. He found is that no bubbles formed inside the cord until a saturation depth of about 24 m (80 ft). Shallower than that there were no bubbles. This data suggests that there was a critical depth, which provided a critical gas content in the spinal cord myelin, which would produce bubbles. This would explain why sport divers who go deeper and longer are more likely to suffer spinal cord injury.

Many people think the brain is involved in DCS, even though there are no clear cut neurological findings. Few people do behavioural testing. Careful psychological testing sometimes shows that there are brain injuries or mental changes with DCS. Some patients have bizarre behaviour patterns with their spinal cord injuries. When they are recompressed they get better, including the

TABLE 2

VOLUME CHANGES WITH DEPTH IN 3 m INCREMENTS SHOWING PERCENTAGE CHANGE FROM SURFACE AND FROM PREVIOUS DEPTH.

All figures rounded to nearest whole number.

Depth in m	Volume in ml	% of original volume	% reduction from surface volume	*Often quoted % reduction in volume for each depth change	Actual % reduction from previous depth volume
Surface	1,000	100	0	0	0
3	770	77	23	23	23
6	625	63	37	14	19
9	530	53	47	10	17
12	455	45	54	7	14
15	400	40	60	6	12
18	357	36	64	4	11
21	322	32	68	4	10
24	294	29	71	3	9
27	270	27	73	2	8
30	250	25	75	2	7

* These figures are derived from the difference between the % reduction in surface volume between two adjacent depths. The true reduction in volume, as a percentage of the volume at the shallower depth, between two adjacent depths is given in the right hand column.

behaviour patterns. Sometimes if one examines a diver carefully, including psychological tests, the results are not normal. People have complained, after a diving accident, that they could not work their computer or they could not write their signature. These are central nervous brain injuries associated with DCS. The reason the brain and the spinal cord are susceptible to DCS is because of myelin. Neurones have myelin sheaths. Myelin is a lipid which has a high affinity for nitrogen and can be easily supersaturated. The brain is also obviously involved in barotrauma and air embolism.

In the past we identified neurological deficits by clinical examination. Now there are some very sophisticated scanning techniques. One can use various radio isotopes or contrast enhancement. One can use CT or MRI. These investigations have been used in many other diseases to study brain and cord lesions. We are beginning to use them to study the brain and spinal cord in decompression sickness. The indications for these kinds of scans are not clear. I think if a diver has a cord injury and there are questions about behavioural patterns or psychological changes it is probably worthwhile doing an enhanced MRI.

Air embolism

The classical description of air embolism was a diver who comes to the surface, cries out, perhaps coughs up frothy, bloody sputum, falls back in the water unconscious, has a seizure and evidence of neurological damage. This description came from submarine escape training done in a hundred foot tower of water. The trainees were quickly pressurised in a chamber, then passed through a lock at the bottom of the tower and made a buoyant ascent, exhaling continuously all the way. Sometimes they wear a hood over the head, sometimes they wear a survival suit but always they must exhale continuously to prevent lung over-inflation. The incidence of pulmonary barotrauma as severe air embolism, at least in the experience of the United States Navy (USN), was about one in seven thousand escapes and about 10% of those would die. The USN has now abandoned this training.

It is rare for that presentation to occur in sport diving. It happens occasionally. What usually happens is a subtle air embolism event. Such as when a diver, who is hanging at 3 m (10 ft), forgets to deflate his BC (buoyancy compensator) as he comes to the surface. He gets a minor pulmonary barotrauma and some air enters the brain, but the diver is not unconscious. He may have minor visual changes, personality change, fatigue, but nothing obvious. This is the new type of air embolism that one must be aware of because some divers who sustain air embolism have non-specific and vague symptoms. The diver who is unconscious after an air embolism can wake up and appear normal, but relapse is common. Diagnostic mistakes have been made in the lucid interval when a physician examined the diver, found nothing and sent the diver home. Four or five hours later the diver was back unconscious with severe neurological abnormalities. A diver with a history of unconsciousness on surfacing, whatever the conscious state, whether they look good or not, should be recompressed and observed for twenty four hours.

Look for irritability and for changes in concentration. Both divers with DCS and with air embolism have complained of such things as being unable to write their signature correctly. There was the accountant who could not add a column of numbers the week after a dive in which he had a brief rapid ascent. No other symptoms were evident, he could not concentrate or add. There are people who went to work on Monday and could not open their computer files because they could not remember the password. If one looks one can find subtle changes. Most sports divers do not panic and ascend uncontrollably to the surface. Air embolisms result from minor mistakes near the surface; trying to clear the mask on the way up, doing a Valsalva manoeuvre as a wave changes the diving depth. There are many things that can occur between 6-7 m (20-25 ft) and the surface which will cause minor barotrauma and minor amounts of air embolism with not so obvious signs or symptoms. Treatment for subtle air embolism is in a hyperbaric chamber using an 18 m (60 ft) table rather than a 50 m (165 ft) table.

Epilepsy

At present the rule is that anyone who has an active seizure disorder or who is taking medication to suppress the seizure disorder should not be diving. This applies to all sport diving and all commercial and military diving. The reason is that if an individual has a seizure in the water, and becomes unconscious, that person will drown. This has happened more than once. In a few instances the buddy, trying to rescue the fitting diver underwater, has also drowned. In the United States, epilepsy advocacy groups support a policy without restriction, suggesting that people with active epilepsy should be allowed to dive.

At the moment it is impossible to tell one person from another in terms of their risk for seizures. Somebody with severe, easily provoked seizures is going to get an easily provoked seizure by exposure to cold water, by hyperventilating, by having anxiety or excess adrenalin. However, it is not clear whether somebody, who has not had a seizure for fifteen years, will be prone to a seizure while in the water. Because we cannot make that differential gradation of risk, we try to give everyone the same risk and say no to diving.

Clearly there are people with minimal seizure risk and yet they get lumped in with any adult seizure disorder which is treated with drugs. Someone who had a fever-associated seizure at six years old, has never had a fit since does not have epilepsy and can dive. Someone who is free of seizures and does not take anti-epileptic medication does not have epilepsy. If somebody had a seizure disorder and has been off drugs for some years, never had a seizure since starting the drugs and has led an active life, can that person dive? In the United States such people have been prohibited from diving for a certain number of years, usually five years seizure free and drug free, then allowed to dive. In commercial diving it would be out of the question. Some neurologists would say that if there is no seizure focus on electroencephalogram (EEG) and there have been no seizures for five years, then the person can sports dive. The approach that I would recommend is that if someone is on drugs for a seizure disorder and the treating physician considers that the drugs must be taken to prevent fits, that person should not dive. The reason is that these people have a seizure focus which is being suppressed by drugs and it is possible that the seizure focus could be activated by diving to break through the drug and cause a seizure. If someone is off drugs and has not had a seizure for four or five years, I generally get an EEG done. If the EEG is normal I allow diving, if the EEG still shows a focus, I say no. None of this is written in a rule. Physicians do not have legal authority to prevent people from doing anything. All one can do is provide advice.

Coronary disease

Coronary disease is a fairly common problem. Sport diving started in the mid to late fifties, so a 22 year old sports diver then is now in his sixties. As the risk of atherosclerosis increases with each year of life, age becomes the most common risk factor that is present. Of course there are cholesterol, hypertension and other factors, but age is the most common risk factor. Unfortunately it is inevitable. There are pills that will lower cholesterol or blood pressure, but no pill will lower age. Sport divers, as time moves on, are at increasing risk for coronary disease. Some of them ultimately get an narrowed artery. The narrowed artery limits blood flow to the heart muscle, the heart muscle does not work well under increasing loads and becomes ischaemic, when it is ischaemic it can either infarct or cause serious or even lethal arrhythmias.

The problem with cardiac atherosclerosis is that it is silent for a very long time. It progresses over time going from a normal vascular endothelium to small plaque formation. These plaques ultimately increase in size until the lumen is occluded by a thrombus. We have learned over the last ten years that plaque growth is not just deposition of cholesterol over time in a steady fashion, related to having high blood cholesterol. What happens is something goes wrong with the endothelium. It is not clear what, we think cigarette smoking has some direct effect on the endothelium. We think hypertension has direct effects on the endothelium, LDL cholesterol has some direct effects on the endothelium, all these seem to make the endothelium less resistant to lipid deposition and other types of injury. The normal function of the endothelium is to resist platelet stickiness and to secrete vaso-relaxing agents which keep the blood vessels dilated. When an artery is injured the endothelium malfunctions, loses the protection against platelet adhesion and stops vasodilatation, in order to protect one from bleeding. This mechanism is excellent for trauma, but there are other triggers for this reaction. With endothelial damage there is lipid deposition. The lipid deposition causes an inflammatory reaction, the inflammatory reaction becomes organised, with calcium, fibrous tissue, cholesterol crystals and smooth muscle proliferation at which stage it becomes a plaque. Later a plaque may rupture. The same process occurs producing another lamination on top of the original plaque. Histologically plaques are laminated like the rings of a tree. Each event produces more occlusion until the plaque rupture causes thrombus formation which occludes the artery instead of just narrowing it. Sometimes thrombolytic agents wash out the thrombus and one finds that the patient only had a fifty percent narrowing underneath the thrombus. Usually the end point is thrombus formation, total occlusion and an infarct. Sometimes an infarct does not occur if the narrowing occurred slowly enough to allow development of collaterals which can carry enough blood to allow occlusion to pass unnoticed.

When one gets into the sixties with no cardiac disease one can be sure that there will be plaques here and there and hopefully some collaterals to protect one from a major catastrophe when one of the arteries occludes. There is no way to know and no one should volunteer for a coronary angiogram without good reason.

Cardiac blood flow and occlusion.

Resting flow in the heart is about one ml/minute/gram. The maximum flow is about 5, so the myocardium has a five to one flow reserve. If one really pushes oneself to extremes (i.e. in competitive athletics) one might get up to four times resting blood flow. Getting five times resting blood flow can only be achieved by reactive hyperaemia after occluding the artery for thirty seconds. One finds that as the cross sectional area is reduced to 80% of normal this ratio does not change very much. Changes are in the range 3-4 ml/minute/gram where very few people ever get. Ordinary walking takes about 1.2 times resting blood flow. A very arduous dive, swimming on the surface with all one's gear on will reach two. Running a mile in 8 minutes one might be up to two and a half times resting blood flow. One has to be into competitive athletics to get up into the threes and fours. We lose flow reserve as we move through 20%, 40% and 60% narrowing with imperceptible reductions in the capacity for blood to go through the coronary arteries. At about 70% reduction in cross sectional area there are large losses in flow reserve. From 80% to 85% there are significant reductions in the peak/resting flow ratio. When the peak/resting ratio is two to one symptoms can be easily provoked. One of the reasons why we worry about divers is that, when people do not exercise very much, they not know that they have limitations. The first time they may sense coronary ischaemia is when they are diving. In the United States sudden death in diving is mostly from acute myocardial infarction. It is usually in people who did not exercise enough to provoke symptoms. The first symptom may be sudden death, which is not an efficient method to determine whether one has coronary disease.

Deciding who can dive and who cannot dive with cardiac problems, is related to physical capacity.

Pulmonary oedema in cold water

Every now and then a healthy middle aged man is exposed to cold water and develops pulmonary oedema. He is helped into the boat, treated and recovers. When investigated nothing abnormal can be found. They were men in their fifties or older, with a history of hypertension, otherwise healthy but not in good physical condition, who went into pulmonary oedema diving in cold water.[3] These were obvious cases of pulmonary oedema which quickly cleared. One suggested mechanism is that vasoconstriction, on entering cold water, in the presence of a raised blood pressure leads to uncontrolled hypertension and ventricular failure.

Asthma

This subject has been well ventilated in the December 1995 issue of the Journal[4-12] so this part of the paper has been very much shortened.

We know there are many asthmatics who dive. There was a survey in a diving magazine, published in the USA, which showed that about 6% of the respondents were asthmatics who dived In the United States about 6% of the population has asthma. Obviously the diving population was not being properly screened. The problem with that survey was that those who dived and died did not answer the survey. So watch out for the controls. But the fact is there are lots of people with asthma who dive. Even asthmatic divers who develop symptoms in the water still dive. I heard this story from a diver. He was on the bottom of St Lawrence River, wearing a dry suit, at 24 m (80 ft), when he had an acute asthma attack. He swam quietly and comfortably to the surface, got on the boat, took his mask off and used his inhaler a couple of times and was fine. There is probably a small increase in risk, perhaps a factor of two in terms of risk for air embolism or decompression sickness. The danger is that the diver's status may change while diving. Cold water, exercise and other things can change a stable non-reactive airway to a reactive airway while in the water. The message in that is if one is a good diver and keeps one's head, one can get to the surface without a problem.

Diabetes

Diabetes is covered in the March 1996 issue of the Journal.[13-15]

Dysbaric osteonecrosis

There appears to be no risk of dysbaric osteonecrosis (DON) in sport divers. I know of a few cases among people who claimed to be sport divers but when one studied them they were making a living as dive guides. They were not sport divers, but they had bone necrosis. Dysbaric osteonecrosis is definitely a disease caused by diving but it is not a disease of the usual sport diver. There are many causes of osteonecrosis. Certain fractures will cause osteonecrosis by damaging the blood supply to the distal part of the bone. Other causes include chronic uraemia, alcohol intake, steroids and decompression sickness. Transplant patients take large amounts of steroids to suppress rejection and osteonecrosis is relatively common.

The Japanese have shown a high incidence of osteonecrosis among divers who followed improper decompression procedures. Not only did they have many cases of DCS, accepted as an essential part of the diver's occupation, but a very high incidence of DON. Total diving experience was the main determinant. Early papers on DON were published about 20 years ago. Dysbaric osteonecrosis can be in the shafts of the long bones, where it produces no symptoms, or close to the articular surface, juxta-articular lesions. These usually lead to damage to the joint surface with joint collapse leading to disablement. Nowadays an artificial joint can restore mobility.

Caisson workers and deep commercial divers also figure in the statistics. The decompression tables used for caisson and pressurised tunnel work prevented DCS but they were ultimately modified to prevent bone necrosis. It is not a sport divers' disease.

Fitness

A brief word about fitness. The major problem for sports divers is being able to handle the physical activity required in diving. If one is in good shape, one's maximum oxygen uptake is higher. One can sustain work at 50% of maximum oxygen uptake on a continuous basis. Working at 70% or 80% is stressful, producing lactic acidosis. If one is in good condition, meaning one's maximum oxygen uptake is increased, a workload that requires 50% of maximum oxygen uptake is comfortable and can be dealt with. If one is in poor condition that same workload would require 70% of maximum oxygen uptake and would be impossible to maintain. A fit diver might handle the workload of swimming 200 m back to the boat against the current after a dive and be short of breath. An unfit diver would get severe lactic acidosis, hyperventilate, panic and risk drowning.

Fitness, measured objectively as oxygen consumption, declines with age, as the maximum heart rate declines with age. It is important to match the exercise capabilities of buddies and groups to prevent older divers from working beyond their capacity.

Calculating decompression

A number of surveys in the United States of trained divers have shown that two thirds could not use a decompression table properly. Certainly there are computers now, but it is still important for people to understand the whole process and to be able to calculate a repetitive dive. Interestingly about one third of the instructors tested could not calculate a repetitive dive using tables. Education is important for diving safety and probably the most important factor in safe diving after making sure that the individual has a reasonable capacity for physical activity.

Audience participation

Greg Leslie

How much disease does a normal thallium scan really exclude?

Bove

Post mortem data shows evidence of plaques even in twenty and thirty year olds. Years ago Clarence Demar, who had run marathons up until the age of sixty five, and won the Boston marathon nine times, died of colon cancer. At post mortem he had dilated coronaries, lots of plaques but nothing that was anywhere near obstructive. Neither a thallium nor a regular stress test would have shown ischaemia. Most people are likely to have some plaques as they get older. Without severe narrowing one is not at risk. A normal stress test shows that there is no ischaemia. There are some data suggesting that if a regular stress test is normal it means the person can handle the exercise, which is the key issue. If a 55 or 60 year old wants to start diving and is not an exercise person, I definitely want an exercise tolerance test to be certain that he or she can handle the workload of diving, which can reach around 13 mets. Thirteen mets is the equivalent of about a ten minute mile jog. It is not a really heavy workload but it is significant, equivalent to swimming against a one knot current with full gear on. A sensible diver does not try to swim against a stronger current.

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OPHTHALMOLOGICAL ASPECTS OF FITNESS TO DIVE

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Abstract

The diving medical examiner may be faced with potential or current divers who exhibit either problems with vision or ophthalmic pathology. A review is presented in which the required visual standards are discussed, together with strategies for correction of common vision problems in the diver. Some of the more commonly encountered ophthalmic conditions are mentioned and their possible impact on fitness to dive is discussed. An attempt is made to consider how eye conditions might be adversely affected by the hyperbaric or aquatic environment. Among conditions reviewed are visual acuity, refractive errors, contact lenses, corneal disease, cataract, glaucoma, retinal detachment, ischaemic conditions, lacrimal duct and orbital abnormalities.

Key words
Eyes, fitness to dive.

Introduction

The diving medical examiner may be faced with questions of a potential diver's fitness in the presence of a previous ophthalmological condition or previous surgery. There have been considerable advances in ophthalmology in the last decade and many examiners may feel that there are gaps in their knowledge of eye conditions, particularly if this knowledge is based mainly on recollection of undergraduate tuition. This review attempts to cover aspects of vision and the eye that may concern the examiner regarding fitness to dive.

The purpose of being fit for a recreational pursuit is to increase both enjoyment and safety. In diving, fitness is important to ensure that the diver is not a danger to himself* or to others.

It is impossible to reduce this risk to zero. The diver may have a right to endanger his own life, but the possibility of endangering others is the more important consideration. It may not be possible or even desirable to reduce either risk to zero, but the diving medical examiner should regard the minimising of danger to others as the primary purpose of the diving medical. The secondary purpose of the diving medical is to minimise the risk to the diver.

* *I have written throughout in my own gender to indicate both sexes.*

Very few conditions encountered in ophthalmology are life-threatening. Very few eye conditions will be a contraindication to diving. Those that are relative contraindications are more likely to cause morbidity in the diver, without endangering the diver's companions or requiring the use of rescue services, and therefore even these conditions may not be reasons to prohibit diving.

Visual acuity

Adequate vision is essential for diving. Sight must be of a standard that enables the diver to locate exit points, such as the shore or the boat. He should be able to see his buddy, locate the shot line, boat and surface, as well as able to see the underwater scenery. Near vision should be adequate for reading gauges, watch, compass and other monitoring equipment.

An exact visual standard for diving is difficult to define. The answer is probably somewhere between the standard required for driving a car and being legally blind. A differentiation should be made between corrected and uncorrected visual acuity. In some subjects with poor vision these are the same. In others, a very poor acuity will be able to be corrected with lenses of some kind. Commercial divers require an uncorrected visual acuity of 6/24 binocularly or better (Australian and North Sea standards) and a corrected level of 6/12 for all divers is suggested,[1] but this is probably too strict. The legal limit for driving a car in Australia is 6/12, but there is little or no evidence for drivers with poor visual acuity having a higher accident rate.[2] Possibly the level of acuity should be set by the individual examiner and a decision made according to the examiner's perception of the subject's handicap and the likely impact on their ability to dive safely. A patient with congenital nystagmus, for example, might have corrected distance acuities of 6/60, but will be little handicapped by this and may have normal or only slightly reduced reading acuity, enabling gauges to be seen clearly.

Refractive errors

Divers with refractive errors are likely to be able to have vision correctable with lenses. The absence of good vision in one eye should not be considered an adverse finding and the vision in the better eye will therefore be the deciding factor.

Hypermetropia (hyperopia) may not need correction in the younger diver, but may cause the same problems as presbyopia, even in the young. The use of a mask with a prescription is probably the most satisfactory means of correction. A dive shop can substitute lenses of spherical equivalent power for the original plano lenses in the mask. This is satisfactory for all but the largest errors or for significant astigmatism. Alternatively a prescription lens can be custom made for the mask or lenses cemented onto the rear surface of the glass. The latter options are more expensive and the stated advantages of the abolition of prismatic effects from better centration are only likely to be of significance in the higher corrections. Custom lenses are the better and more comfortable option.

Upon loss of the mask, the normal diver becomes about forty dioptres hypermetropic underwater, a degree of hypermetropia much larger than that ever seen in practice. Those who have experienced loss of a mask will realise that it is still possible to terminate a dive safely, even with such a large uncorrected refractive error

Myopia gives poor distance vision. A majority of myopes are comfortable for near vision without correction. Again lenses incorporated in the mask are satisfactory. Contact lenses give a better correction of myopia than glasses. More myopes will wear contact lenses than hypermetropes.

Presbyopia is the loss of accommodation with age. A reduction in close-focussing ability begins about eight years of age. About three dioptres of accommodation are needed for reading at normal distance. People are comfortable when using about two-thirds of their available accommodation for any length of time, so difficulty begins to be experienced with lack of accommodation when accommodation is reduced to about four dioptres. This usually occurs after the age of forty. Normal print usually requires reading glasses in the forty five year old. Presbyopia is said to have appeared at this event. The presbyope will find reading easier in bright light due to the enhanced depth of field with a small pupil. Symptoms will be worse in poor light, especially in the evening when tired. Pre-existing myopia enables reading to continue unaided for longer and hypermetropia causes glasses to be required earlier.

The refractive index of water causes objects to appear closer and exacerbates presbyopia. The higher refractive index, as well as making objects effectively closer, causes magnification to the same degree. This magnification may decrease the effects of presbyopia. Available light is reduced as one goes deeper. At 10 m there is only 20% of the light available at the surface and only 1% at 85 m, which makes presbyopia a greater problem for the diver. A theoretical assistance with presbyopia is the chromatic shift of light towards the blue with increasing depth, which can assist with about half a dioptre. Early presbyopes can manage, for a year or two, by choosing new gauges, computers and watches with large clear displays but corrective lenses are eventually required. Presbyopic divers require a near lens to see their gauges and for close work. Some use a small lens cemented on one side of the mask. The diver looks at the wider world through the unmodified glass. Some presbyopes wear a near contact lens on the less dominant eye, to give a mixture of a focussed and unfocussed image at both distance and near. Presbyopic myopes can leave one lens of the mask unaltered if reading gauges is a problem. Many find this deliberate unfocussing of one eye, unacceptable. Unfortunately these are stop gap solutions as most presbyopes require stronger lenses with the passage of time and end up with bifocals on land. The most comfortable solution is to accept that one is ageing and have reading prescription lenses put, as the bottom half of bifocals, in one's mask as soon as one cannot read the telephone book without glasses. Not only can one then read one's gauges but also admire the details of small shrimps and other tiny sea life.

Contact lenses

For correction of both myopia and hypermetropia contact lenses can be worn in conjunction with the diving mask. Soft lenses are less likely to be lost than hard in the event of a mask flooding. Contact lens wearers should consider wearing a mask containing a purge valve as, in the event of a mask flooding, mask clearing may be achieved with less risk of losing a loose contact lens.

The formation of air bubbles under contact lenses on decompression has been described,[3] with localised transient corneal opacities. These are not likely to be harmful, or even likely, in recreational diving. Disposable lenses are a good option for the contact lens wearer. Their low cost and the need to carry spares assists easy replacement before the next dive, if lenses are lost.

Visual field defects

Visual field defects are commonly found in neurological disease, glaucoma, and disease of the retina and retinal pigment epithelium

Patients with field defects due to neurological disease may already be inherently unfit to dive. Hemianopia or quadrantanopia per se is not a contraindication to diving, but the causative neurological damage may make the diver more susceptible to other effects, such as cerebral decompression sickness, oxygen toxicity, the exaggerated effects of narcosis and exaggeration of other problems related to the hyperbaric environment.[1]

Severe visual field defects with restriction of field to less than 20° would be likely to be a visual handicap when diving, but the normal diver has a field restricted to about 30° on either side of the midline by the face mask.

In glaucoma, restricted fields are characteristic of the end stages of this disease. For other reasons patients with advanced field detects from glaucoma might be advised not to dive (see Glaucoma below).

Patients with Retinitis Pigmentosa can appear quite normal and yet have problems with both night blindness and tunnel vision. Both these defects have the potential to cause problems diving in the dimly lit world at depth. Formal visual field testing should be performed if this condition is suspected. Not everyone with this disease knows that they are affected. The optic fundus can appear normal on ophthalmoscopy. Narrow retinal blood vessels, pale discs, and scattered pigmentation in the peripheral retina can sometimes be seen.

Corneal pathology

The main effect of corneal pathology will be to reduce visual acuity and reduced vision can be the only sign of corneal disease without slit-lamp examination. Corneal scars, corneal dystrophies, and keratoconus if significant, will result in reduced vision. Keratoconus (conical cornea) is a dystrophy that produces progressive myopia. In the later stages vision can only be corrected with contact lenses. Later even contact lenses are not able to correct the eyesight which can only be done by corneal grafting. Corneal irregularities due to scarring or corneal dystrophy render the eye more susceptible to abrasions and ulceration. Under normal circumstances this will not affect the diver, but a combination of exposure to non-physiological osmolarity and contaminated water could cause serious infection. Some tropical environments, where the coastal water has a heavy faecal contamination, cause a high incidence of eye infections and could be dangerous in the presence of corneal disease. The condition of recurrent corneal erosion can be treated with hypertonic saline eye drops and exposure to hypertonic sea water could be beneficial to patients with this condition.

Recurrent benign microscopic corneal ulceration occurs in the condition known as Thygesson's Keratitis. This is characterised by episodes of discomfort and photophobia and is believed to be due to residual virus in the corneal epithelial cells following infection with a number of infecting agents. Less benign ulceration, also of a recurrent nature, occurs in Herpes Simplex Keratitis. This is due to emergence of lysogenic phase virus in the corneal epithelial cells or keratocyte stromal cells following a primary herpes inoculation in infancy. The majority of people receive the primary inoculation through the oral mucosa and do not subsequently get herpetic keratitis. Exacerbations of corneal herpes occur following minor trauma to the cornea. Diving itself is not implicated, but sun exposure can be a predisposing factor. There are no absolute corneal pathologies that would debar the aspirant diver, but care could be advised.

Corneal surgery

Kluger[4] has recently published an excellent review on this subject. Surgical correction of myopia has been attempted since the work of Sato.[5] A more recent adaptation of Sato's operation has been popularised by Fyodorov,[6] and is known as Radial Keratotomy (RK). Many people have had this procedure done in order to participate in sport. The procedure involves several radial cuts through 95% or more of the corneal thickness avoiding the central optical zone. In practice, the depth of the cut often exceeds 100%, producing aqueous leaks and microscopic corneal perforations. The cornea is flattened by this procedure and myopia may be abolished. The corneal stroma effectively does not heal after RK, as evidenced by the continuing advancement of the correction in many patients, with eventual development of hypermetropia. Concerns about this procedure are the weakening of the corneal structure and the potential for infection. Many patients experience sensitivity to glare and fluctuating vision due to movements of the central flail section of the cornea. Mask squeeze has the potential for causing movement of the cornea, as well as reopening aqueous leaks. In practice, perforation or leaking due to mask squeeze has not been described. The strength of the cornea depends on epithelial healing, and reformation of the inner Decemet's membrane where micro perforation has occurred. Trauma can certainly cause rupture of the globe at these sites,[7] and infection remains a possibility. Because of potential problems military personnel are not permitted to have Radial Keratotomy,[8] The author has seen corneal abscess formation occurring in an RK wound eight years after surgery. The potential diver should be warned of the possible problems. RK is not a contraindication to diving, but diving should be avoided until the wounds have healed, externally. This should be complete after six weeks or less.

Myopic correction using the excimer laser in the procedure known as Photo Refractive Keratotomy[9] (PRK) is likely to become more common and may eventually replace Radial Keratotomy. In PRK, the central 5 mm or 6 mm of the cornea is reshaped according to a computer model, using the photoablation capabilities of the excimer laser. Many patients have now been treated by this technique and good success has been achieved even with patients with moderate myopia. The weakening of the cornea is minimal and once epithelial healing has occurred there is no increased risk of infection. Excimer is now being used to treat hypermetropia, by ablating layers of the corneal periphery under a superficial corneal flap, and thus creating a steeper central cornea. PRK is not a contraindication to diving The military may accept people who have had PRK. Patients may dive once external epithelialisation has taken place.

Corneal grafting means a penetrating keratoplasty in most cases. Precautions need to be taken while the corneal wound heals and develops strength. Typically, sutures will remain in place for up to a year and much of the early strength will depend on the suture. Severe squeeze, and even minor trauma should be avoided. Three to six months should elapse after grafting before diving. There will be some risks up to twelve months. Onlay grafts are sometimes used for refractive correction and are unlikely to cause problems beyond the postoperative period.

Cataract surgery

Cataract surgery is the commonest operation in the world. Today, surgery for cataract means a lens implant procedure. Even young patients can have cataract surgery although the majority of patients are over sixty. There are basically two different techniques used for cataract removal. In extracapsular cataract surgery, the lens is removed through an upper corneal or corneo-scleral wound. This wound is sutured and sutures remain in place below the epithelium or are subsequently removed. The wound has little inherent strength, and surgeons may advise against stooping or straining for some weeks. The wound will have gained strength after three to six months. In the second technique, a small wound is used to insert the instrument known as a phacoemulsifier, and the cataract is removed in the process of phacoemulsification. It may be possible to achieve lens removal and the insertion of a folded lens implant through wounds as small as 2 mm to 3 mm. Such wounds are constructed to be closable flaps and may be so stable that one or even no sutures are required. These wounds are corneal or scleral and have strength even before healing has commenced. Contact with the aquatic environment should be avoided until the external wound is sealed, but this may be only days after surgery. Since the eye is fluid filled there are no special problems with depth as such, but avoidance of mask squeeze is wise, especially in the extracapsular procedure.

Glaucoma

There is no single disease called glaucoma but many glaucomas. Because some of these conditions are characterised by the presence of raised pressure inside the eye, there is often concern about the possible impact of exposure to hyperbaric conditions on the glaucoma patient. The short answer to this is that diving has no adverse effects, but this ignores some of the possible less direct effects of both the diseases and their treatment.

Glaucoma is characterised by progressive visual loss due to a perfusion failure of the circulation of the anterior optic nerve. Such visual loss is seen in characteristic patterns. Glaucoma is an ischaemic disease rather than a pressure disease. A common cause of this ischaemia is raised intraocular pressure. Currently reduction of pressure is the therapeutic approach to improving perfusion, or preventing perfusion failure from developing. This approach is not successful in all people. Raised ocular pressure may be the commonest cause of reduced ocular circulation, but it is not the only one, and other means may have to be taken in an attempt to improve perfusion. For example, patients with glaucoma must not smoke. Patients with established field defects are more susceptible to further damage.

Like all liquid filled organs the eye assumes ambient pressure and is unaffected by diving. The diver with glaucoma may however encounter other problems. The mainstay of current glaucoma treatment is the β-blockers. Timolol (Timoptic) may cause bradycardia and reduce tachycardia on exertion, which could affect the diver's fitness. Bronchospasm may also occur. Betaxolol and other selective β-blockers are less likely to cause these unwanted effects and may be inherently better for the ocular circulation.[10] Oral carbonic anhydrase inhibitors are used less than in former times for long-term control of glaucoma, but they will affect carbon dioxide (CO_2) transport, with possible concerns of the effects of enhanced CO_2 retention, and metabolic acidosis. Increased retention of CO_2 may enhance the effects of nitrogen narcosis.[11] Diving should be considered unsafe with a drug which directly affects gas transport.

Glaucoma surgery is designed to reduce ocular pressure by producing a fistula by which aqueous humour can bypass the poorly functioning drainage meshwork and gain access to the circulation. Aqueous leaks from the eye into the subconjunctival space and is absorbed by the episcleral vessels. A closed system such as this is unlikely to be affected by diving, but occasionally drainage blebs are extremely thin walled and, although not affected by overall changes in ambient pressure, can be perforated by direct trauma. The chance of this happening during diving activities seems unlikely. A thin bleb may allow access of bacteria to the inside of the globe during a conjunctival infection. Ophthalmologists whose patients have thin blebs should warn patients to seek treatment for episodes of conjunctivitis.

Other potential ocular ischaemic problems

It is convenient to consider these immediately after glaucoma. A condition indistinguishable from glaucoma but with normal or low ocular pressures is known as normal (or low) tension glaucoma. This is commoner in subjects with a tendency to vasospasm or migraine. It is unknown whether exposure to cold would worsen ocular perfusion. Carotid insufficiency is exacerbated by head position and exposure suits. Patients with normal tension glaucoma or carotid disease should probably not dive.

Normal divers have been shown to have closure of capillaries in the juxtamacular capillary bed of the choroid on routine fluorescein angiography (M Cross personal communication). The significance of this finding has yet to be established. It is thought to have been caused by silent bubble formation. Vision was not affected. There is no recorded higher incidence of macular degeneration or other problems even in occupational divers

Patients with demyelination of the optic nerve may exhibit Uthoff's Syndrome, a reduction in visual acuity with a rise in core temperature, due to exercise.[11] Such patients may demonstrate an improvement in vision with cooling. Uthoff's Syndrome can be present in otherwise fit athletes and might present in a diver during suiting up on a hot day or during a strenuous surface swim.

Retinal conditions

Patients with moderate to high myopia (more than six dioptres) have an increased risk of retinal detachment. Retinal detachment is often precipitated by ocular trauma. Football, boxing, and other contact sports should be prohibited. Scuba diving is unlikely to cause a significantly increased risk of eye injury and should be permitted if corrected vision is adequate.

After retinal detachment surgery, diving will be permitted after the initial post-operative period. The purpose of surgery is to reattach the retina and successful surgery will produce a stable retina, unlikely to detach again. Diving will not increase the risk of re-detachment. Surgery consists of sealing the holes present in the retina by laser or cryotherapy. This produces a scar which attaches the retinal hole on to the retinal pigment epithelium and choroid. Usually this is combined with some kind of volume reducing procedure to assist in the development of good adhesion between the retina and the wall of the eye. A localised indent of the ocular wall can be produced by an external or internal plomb. An external plomb can consist of synthetic foam rubber. Although some of the cells will become fluid filled after surgery, a number of small gas-filled cells will be present in this type of plomb and the plomb will behave like a small piece of neoprene. It may therefore compress with depth. This is not likely to cause detachment of the retina, as once reattachment of the retina has occurred, many plombs can safely be removed. Sometimes a plomb is essential to relieve traction on the retina from internal strands within the vitreous, but problems from a combination of vitreous traction and plomb compression seem unlikely. The relief of traction from the vitreous is more commonly achieved by its removal and relies less on external indentation. Many surgeons use solid silicone plombs and the use of sponges is now less common

Air or inert gas bubbles are used for internal tamponade of retinal holes during retinal detachment surgery. A gas such as Sulphurhexafluoride (SF6) is chosen for its high molecular weight and slow dispersal rate. If pure inert gas is injected (the patient remaining at 1 ATA), the bubble will subsequently expand to undesirable size due to its initial low partial pressure of nitrogen and proximity to the blood supply. Conversely, a pure air bubble will disappear rapidly. If a mixture of air and inert gas is used then a bubble can be introduced which lasts up to several weeks. A typical mix of 20% SF6 and 80% air behaves as a "volume neutral" bubble, remaining of similar size for some time. Obviously diving, involving changes in both ambient pressure and tissue partial pressures, is not advisable during the persistence of such bubbles. Patients will be unlikely to feel well enough to dive for some weeks and therefore not diving while under post-operative care is sufficient prohibition.

Lacrimal and orbital conditions

The lacrimal sac and tear passages normally contain some air. A free communication exists between the lacrimal duct and the nasal cavity through an opening below the inferior turbinate bone. Raised pressure inside the nasal cavity during equalisation manoeuvres normally does not cause inflation of the lacrimal sac, since this opening acts as a valve, but occasionally air entering the tear passage can cause a jet of liquid to eject through the lacrimal punctum. Following surgery on the tear passages, nose blowing frequently causes a draught of air onto the eye. Partial blockage of the tear passages can occur with disease of the lacrimal sac, or following nasal fractures, creating a potential enclosed air space susceptible to barotrauma.

Fracture of the medial orbital wall of the orbit is common with blows to the eye or orbit.[13] Air can enter the orbit, causing surgical emphysema during ascent or the Valsalva manoeuvre.

Blind divers

Blind people, unlike the deaf, will be disadvantaged in the subaquatic environment. Diving is a very visual sport and there seems little point in the blind wishing to dive. However there are programs for blind divers in various parts of the world where they follow ropes over the bottom and markers are provided so that they can explore various features of the bottom by feel. Adequate backup and safety provisions should be in place in case of difficulties. Experienced sighted divers sometimes find themselves in a zero visibility dive and the blind person will obviously cope well with a dive under similar conditions. To dive safely the individual diver has to be able to cope with his own problems, and if timers and gauges are not able to be read or felt by the individual, then diving should not be permitted. Under some circumstances, diving might be permitted with a one-to-one supervision and tethered by a buddy line to an experienced diver, but should be restricted to safe and shallow dives. The blind should not be medically certified as fit to dive unless for single resort-type dives as part of a life experience under expert supervision.

Conclusion

Providing criteria for corrected visual acuity can be met, eye conditions rarely affect a diver's fitness to dive. Those that do may only be a relative contraindication. General rules about diving and medications apply. Glaucoma medications, and in particular carbonic anhydrase inhibitors, are likely to be the main reasons for a diver being classed as unfit. Previous eye surgery should not prohibit diving once the immediate post-operative period has passed. Some surgical procedures create a wound which affects the strength of the ocular integument, but this is not adversely affected by changes in ambient pressure. Severe mask squeeze and direct trauma to the eye should be avoided following eye surgery.

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DIVING MEDICAL DILEMMAS

Cathy Meehan and Guy Williams
with audience participation

Key Words

Asthma, cardiac problems, drugs, ENT, injuries, investigations, medical conditions and problems, treatment.

Introduction

We offer some examples of common diving medical problems seen by us in our diving medical practices. We hope that members of the audience who have opinions will state them.

Ventricular septal defect

A medical practitioner came to see me last year for a diving medical. She had a small ventricular septal defect (VSD) that had been proven on echocardiogram many years ago. She was otherwise completely well. When I saw her I understood that the standard practice in diving medicine in Australia was that candidates with atrial (ASDs) and ventricular septal defects were both classed as being unfit for diving. She is quite interested in the results of this discussion. The cardiologist, who performed her echocardiogram last week, suggested that he would advise her to have her VSD repaired to reduce the risk of endocarditis.

I would like to have opinions on this matter from anyone.

Andy Veale

If you move away from the concept of fitness or unfitness this person is at low medical risk and may well choose to dive.

Bove

The important thing about a VSD is whether it is haemodynamically significant. The pulmonary artery pressure is stated as being normal in the cardiologist's report. The only chamber that gets volume overloaded in a VSD is the left atrium, the flow just squeaks across the septum and out up the pulmonary artery so it does not load the right ventricle. The left ventricle is not affected unless the VSD is very large. She has a small VSD that makes noise. The general practice has been to leave them alone and warn the patient about antibiotic prophylaxis for endocarditis. A VSD does not reverse to right to left so the shunt is not a risk for bubbles to reach the left circulation. She is fit for diving.

Chest injury

Williams

Two or 3 years ago a 29 year old came in for a diving medical. In the past he had had a motor vehicle accident, sustained some fractured ribs and had, from his description, a haemopneumothorax that required a chest tube. He did not know much more than that. His chest X-ray was normal, his lung function tests were normal. I tried to obtain details of his medical history from the treating hospital, but they still have not arrived. The candidate never contacted me again, so he either lost interest in diving or went somewhere else. I would be interested in the audience's comments on somebody diving after they have had a penetrating chest injury of this sort.

Veale

On the data provided his potential medical risk is areas of varying lung compliance within the area of lung damaged beneath the rib fracture. Whether you believe Colebatch's data or not this individual may have a small increased risk over the risk that he would have had had he not been injured. You could help quantitate that a little better by doing a high speed helical CT scan in inspiration and in expiration to see if there were areas of air trapping within that area of lung. If there were not I would say that he was at low medical risk and that he may well choose to dive.

Bove

I do not worry about pneumothoraces in someone who had a traumatic pneumothorax. He is not in the category of someone who had a spontaneous pneumothorax . The main concern is the possibility of regional differences in lung expansion. There are many people diving who have had traumatic pneumothoraces. I had a pneumothorax from chest compression in a near drowning accident a long time ago and I have had no trouble yet I know many people who have had traumatic pneumothoraces who have not had any problems diving. I think the shear force problem would occur with over expansion, which might make the lung more sensitive to injury than if it were not stuck down by adhesions. Most people have good chest dynamics long after the injury has healed and do not have a problem.

Two cases of epilepsy

Williams

Case 1

This man, a 44 year old ex-commercial diver, is now a keen sports diver. Twenty six years ago he was diagnosed as having idiopathic epilepsy. He has been on anti-convulsant therapy ever since. He has not had a fit for 25 years. He has an absolute obsession with medication compliance and will not stop his medication. He has quite extensive commercial, mostly overseas, and sports diving experience. He did not admit to being an epileptic whenever he had a diving medical. He is aware of the risks. He has been advised by his neurologist that he should not be scuba-diving. I told him that I thought that conventional wisdom would fail him on a diving medical. He has never been to me for a diving medical. He attends my practice for other matters medical but he goes to other doctors for diving medicals and he deliberately does not tell them that he is an epileptic.

Case 2

A 23 year old was certified for sports diving in 1986. He had 3 convulsions in 1990 following some fairly heavy partying. It was thought that these were probably brought on by his life style at the time but he did have an abnormal electroencephalogram (EEG). He was placed on medication and advised by myself and his neurologist to cease scuba diving. He was otherwise quite well. He was on a fishing boat on the Torres Strait for a couple of years until early 1995, when he came back to holiday in my area. He had stopped his medication in 1994. He had taken no medication since and had no fits. He asked me if he could scuba dive. I suggested we would really have to refer him back to his neurologist and perhaps have another EEG. He said “Thanks doc. I’m going up to Cairns for a holiday. I’ll be back in 2 weeks and we’ll do that”. While he was in Cairns he enrolled himself on a dive master course.

Now my question is given these two people’s histories, would anyone here be happy to pass the first man?

Veale

The first man has had a provocative test probably 500 times from the time of his onset of his epilepsy. He has had no seizures for 24 years and many people would say that he no longer had epilepsy and should not be on medication. He has stood the test of time so to speak. The second chap is at higher medical risk and should be advised not to dive.

Williams

I used to go diving regularly with the first man who has not been diving for a couple of years because he developed an illness that was incompatible with diving and until he recovers from that he does not feel like diving.

I last saw the second man in January 1995, in February, while he was in Cairns, he was swimming, disappeared from the surface and drowned. The results of the Coroner’s Inquest are not yet available (May 1995).

Unidentified speaker

My understanding is that if one takes a PADI Dive Master course one needs a repeat medical, is that correct?

Richardson

Yes.

Meehan

He had started a dive master course without a medical and was working with one of the dive companies on a boat as the deck hand and helper while he was doing his dive master course. A lot of the dive master medicals are not done before the course, but during it. They are done before the paper work goes off to PADI. He had not yet had the medical.

Unidentified speaker

I think this raises an issue which I come across time and time again, and it relates to all the organisations, not only PADI, that very often divers present for medicals well into their dive courses, sometimes even after they have completed the open water training.

They will not be given their ticket by the dive school until they have got their medical. The best example I have of that was a young women who had quite severe symptomatic asthma, which she ticked on her box, but they had allowed her to complete the course. She also had a severe psychotic illness and had had three admissions for attempted suicide within the previous twelve months. This lass is an extreme example, but I am constantly worried by the fact that dive schools and diving instructors are very casual about where, in the framework of training a recruit diver, the medical is completed and the documentation completed to their satisfaction. Now obviously training organisations must have a standard of practice. It seems to me that the reality does not quite fit with their intentions.

Williams

I am quite confident that if he had had a medical in Queensland that he would not have informed the doctor of his fits.

Bove

In the United States a large number of diving accidents are related to alcohol. My question is, did he stop the seizure medications and the anti-seizure medications or just the anti-seizure medications? I have a feeling that this young man was fond of some ingested seizuregenic medications which may have contributed to his drowning accident.

Williams

I believe he mellowed his ways but he was still a wildish chap.

Chairman (Davis)

Just before we leave the epilepsy question it is important to remember that hyperventilation, sleep deprivation, alcohol and alcohol withdrawal are very powerful epileptogenic stimuli and that people have different seizure thresholds. I think that even those who had a childhood febrile seizure may well have a lower fit threshold. Even if they have not had seizures for a long time I tell them about sleep deprivation, alcohol etc.

Davies

A comment on the oxygen tolerance test. I know that various navies used to do it but why, I do not know because Kenneth Donald in 1940s showed that it did no practical good at all. One cannot predict when somebody is going to fit on oxygen. I know from our experience in Fremantle that a patient might have quite a few treatments in the chamber, and then suddenly, out of the blue they have a fit. It is totally and utterly unpredictable.

Chairman (Davis)

It is also governed by things other than oxygenation, particularly pH which is due to ventilation, temperature and a whole range of factors which modify the test.

Unidentified speaker

If you had known this man was going to do a Dive Master's course next weekend, would you ring up the dive training organisation and say this man is epileptic and must not do the course?

Williams

I think he had not consented to something like that, so I would not have rung.

Unidentified speaker

Because the man is going to be a Dive Master, he is going to be putting other lives at risk. And from a legal point of view, it has been tested that, when the public good outweighs the individual's good, the issue of privacy is not legally valid.

Williams

I do not think I would have informed the dive training organisation. I had not seen him since the 1986 dive medical. On my dive medical form I have a section that I ask candidates to sign which states that they consent to the results to the examinations being forwarded to the teaching organisation. I have never had to do it. This man came to see me for something completely unrelated to diving. He just happened to mention that he wanted to get back into diving at some time. It is all an unfortunate disaster for him and his family.

Chairman (Davis)

You do raise an important issue though, and certainly in New Zealand, the need to notify in that situation would be an acceptable breach of patient confidentiality within the law.

Nine asthmatic cases

Williams

Case 1

A forty six year, old self employed builder, came bustling into my surgery saying that he was big and strong and fit, that he had done everything and now wanted to do diving. He was otherwise quite healthy, a non-smoker, admitted to a past history of wheezing with hay fever which was basically seasonal. His lung function were not normal. He stated that he was otherwise completely healthy, never had a problem in his life. I thought from his story, and the fact that he was fairly vague and evasive about his history of wheezing with hay fever, that he probably had a history of asthma and just was not declaring it to me.

I referred him to have a challenge test. Shortly after that at a school barbecue I happened to meet his dentist, whose son goes to school with our son. He asked me if I had seen "Joe Bloggs" for his diving medical and whether I had passed him.? I said "No, I have organised some further tests". The dentist said "I do not know whether I should tell you this, but my conscious dictates that I do, as I know this man. He has been in intensive care with life threatening asthma attacks on three occasions". I immediately became not at all keen to subject him to a challenge test. I rang the laboratory, but the builder had already cancelled it himself. Optimistically I thought, this is nice, he has seen the light, he has decided to do the right thing and not to take up diving. A month later I met the dentist at another school barbecue and he asked me again "Did you pass "Joe Bloggs" for his diving medical?" I said, "Well no, we never actually completed it. He never came back." And the dentist said, "I thought you would like to know that at this moment he is diving on the ninety foot sub doing an advanced diving course". He had obviously gone off and sought medical opinions until he could find a doctor who would pass him.

Case 2

Most of the medical representatives in our area know that I have an interest in diving medicine because I have solicited every one of them for sponsorship for SPUMS. One asked me about whether she would be able to dive. She was on chronic medication for asthma and occasionally used a Ventolin puffer but was otherwise quite fit and well. I do not really know much more about her medical history. I had just bought a new spirometer and wanted to test it so I tested her lung function. Her lung function tests were pretty reasonable for somebody who was alleged to be an asthmatic, being normal. The point is that, if this young woman had not ticked asthma in her box, there is no way I would ever have picked it.

Veal

Quite true.

Williams

Case 3

A nineteen year old student, non-smoker, past history of hay fever, who occasionally wheezes when he gets hay fever, uses Ventolin, otherwise normal, lung function tests reasonably normal, hypertonic saline challenge test, no response.

Case 4

A man and his wife, both teachers, both wanting to take up diving, came in recently. He gave a past history of asthma, hay fever, uses Ventolin occasionally, gets exertional asthma and had abnormal lung function tests. I had a discussion with him on the risks of asthma and diving, and gave him a copy of an article that Carl Edmonds wrote, on asthma and diving, which frightens most people. He read the article and simply said "I did not realise there was any risk. I have lost all interest in diving. My wife will dive. I will snorkel. Thank you."

Case 5

A school teacher, who had some previous diving experience in the Solomons. This may have just been some resort dives. He admitted to getting short of breath with hay fever and to being a very atopic person. Occasional smoker. Poor lung function tests and he failed his methacholine challenge test quite miserably. The point here is that he had already tried diving in the Solomons and not had any problems. I failed him on the basis of the methacholine challenge.

Case 6

A man with a history of hay fever and becoming wheezy with his hay fever. He had a 20% drop with hypertonic saline. That happened within a couple of minutes and he was becoming quite distressed, in spite of the fact that he sat there saying "I feel alright. I am not wheezy. I am OK." But he was looking quite ill by the end of it and the drop reversed quite quickly with some Ventolin.

Case 7

A man with a history of hay fever, exertional shortness of breath and the occasional wheeze, with a strongly positive histamine challenge test.

Case 8

A fifteen year old gave a history of asthma as a child, but nothing recently. His lung function tests were below normal and I thought he probably had asthma. I referred him to a respiratory physician who did some more lung function tests, and diagnosed him as having moderately severe asthma. He also stated that this particular boy had no perception of air flow obstruction. He did not recognise when his lung function was extremely poor. He obviously failed.

Case 9

A man, with a history of hay fever, had wheezed as a child, but otherwise quite well since and he had no response to hypertonic saline.

The reason for presenting all these patients with a respiratory history is to try to get some guidelines, not necessarily today, but certainly as the rest of this week progresses, so that those of us who do diving medical examinations can give people more reasonable responses. At the moment I do hypertonic saline challenge tests on all people with a history of asthma, wheezes and hay fever, who have reasonable lung function. Those that fail the challenge I fail, and those that pass I allow to dive. Asthma and wheezes make up 90% of the problems in assessing diving medical fitness.

Chairman (Davis)

At the New Zealand Chapter meeting a few weeks ago we had a very similar session where a number of so called "asthmatic cases" was presented which provided a very similar spectrum to this one. Andy Veale was meant to lead the discussion, but he could not make it because of clinical commitments. Andy Veale is a specialist in respiratory medicine at Green Lane Hospital in Auckland, so I am going to get Andy to comment first on that series of cases.

Veale

I will just make two comments. First, 25% of the people that I see with a previous diagnosis of asthma, do not have it. Exercise induced asthma is often an inspiratory noise associated with laryngeal inco-ordination, and these people have no hyper-responsiveness at all. The second comment is that 10-15% of you in this room, if I grabbed you now, would have non-specific bronchial hyper-responsiveness. And, under the current suggestions, would not be diving tomorrow.

Bove

What is the perceived risk for most of these folks who have normal pulmonary function tests and seasonal wheezing. The DAN data from the United States, on many thousands of divers, suggests that there is either no risk or minimal risk for these individuals from diving. As far as I can see there is no problem with these people, and at least 10% of the divers in the United States are these kind of people. The only people who had problems in the DAN data are people who were actively wheezing asthmatics.

Chairman (Davis)

I do not want this session to develop into a general discussion of asthma. Now that Fred and Andy have commented and provided the basis upon which to consider the workshop on asthma later in the week, I will ask Cathy Meehan to present her cases.

Abnormal lung function tests

Meehan

This is respiratory problem which we often get. Most people I see in Cairns are fit healthy backpackers. This was a 25 year old Swiss male was visiting Cairns specifically to scuba dive. He had no significant history, was a non-smoker, had done several resort dives and was very active in Karate. He was 182 cm tall. FVC was 97% of predicted value. FEV_1 was 79% of predicted value. His FEV_1/FVC ratio was 67% and his FEF 25 to 75 was 52%. Examination was completely normal. His lung function tests were below the standard for diving. He did not accept this, so was referred to a respiratory physician who examined him, could not find anything at all wrong with him nor any reason for his poor lung function. He was assessed with a hypertonic saline challenge test which was completely normal. He was challenged with a bronchodilator and showed no response. Has anyone any comments on whether this young man is fit to dive or not, or any further investigation.

Chairman (Davis)

My FEV_1/FVC ratio is 64 % of predicted normal. That is caused by an inappropriately large FVC. My FEV_1 is normal. However, I have no air trapping and my FEF 25-75 is near normal. We do not know whether it is the limitation of flow which places people at risk, or indeed if there is any risk. The standard error for FEF 25-75 is plus or minus 35%. It is meaningless data really. The scatter, once you get away from the standard measures of FEV_1, FVC and the FEV_1/FVC ratio becomes very broad, and if you look at FEF 25 it is even plus or minus about 55%. I would do a chest X ray and a test of gas trapping in this man to help quantify his risk a little better, because it is conceivable that he may have had sarcoidosis in his early youth and have bronchostenosis. But that is really the only thing that would concern me, and without that additional data I would have to advise him that on this it is possible he could be at trivial increase of risk. If he asked me whether I would dive with those lung functions I tell him I do.

Meehan

Our chest physician suggested that maybe he should have an alpha 1 anti-trypsin level done. His chest x-ray was normal. He was not passed fit for diving.

Radiotherapy to the chest wall

Meehan

A 37 year old British female physiotherapist was in Cairns visiting friends, who were diving instructors at the local dive school. She was a marathon runner and had recently had occasional coughing with extreme exercise. She had been given Ventolin to use prophylactically by a doctor friend and found that this did help. She had no past history of asthma or atrophy. Her spirometry was completely normal. Because she had ticked that she had wheezed, I spoke to her before we started the dive medical. At this stage I suggested that if she did want to dive she would have to have a hypertonic saline provocation test. Would anybody fail her on that history, or have any other comments as to what they would do next?

Unidentified speaker

I would pass her without further testing.

Meehan

She gave a history of breast cancer, a partial mastectomy and five weeks of radiotherapy, five years ago.

Veale

Well again we come back to the theoretical risks, shown by Colebatch, of areas of varying lung compliance. The area of the radiated lung behind the breast will have some scarring. If one assumes that Colebatch's data is worthy of precluding somebody from diving, then one would stop this person from diving. Looking back at his original data there were five times as many people that one would exclude from diving on the basis of variable lung compliance for every affected individual. I would do the same sort of work up that I would do with the lung trauma type patient, to see if there were areas of localised impaired emptying of the lung. The best tool is an inspiratory and expiratory high speed CT scan. Irrespective of the outcome of tests, I think that she is at relatively little increased risk.

Bove

I feel the same way. In many of these cases we do not have outcome data. We are making assumptions based on theoretical issues without any evidence that there is an alteration in outcome attributable the theoretical assumptions. I think it is quite dangerous to exclude people without good outcome data. I feel that a patient like this would be perfectly safe to dive, but should be advised that there may be a small increased risk. We do not know what it is. It might be interesting, some day in seeing all the patients that you see, to develop some sort of an informal randomisation scheme and let some of them go diving and ask them to come back a year later to see what happens. I do not like to practice medicine with no data. It is not a good way to deal with the patients.

Chairman

I think that the audience can see from this series of patients why Des Gorman presented his paper regarding the underlying principles and philosophy behind health surveillance and assessment, on the first day.[1] I want everyone to think about these cases in relationship to that structure, because what we are quite clearly seeing here is that the vast majority of practitioners who are interested in diving medicine adopt a combined prescriptive and facilitatory approach to the assessment of diving health. There are certain levels below which we are not happy at all and then there is an area beyond that where we need data. In practically all these areas there simply is no adequate epidemiological data. We have to be the guiding physician and advise people of the risks that we believe may be involved, but we can only do that in very broad terms.

Multiple sclerosis ?

Meehan

A woman traveller had pins and needles down the left side of her body for one month, just before she left England, a year ago. She had a CT scan at that time which she said showed some small scars on the brain. She had been seen by a neurologist, who said the diagnosis was uncertain but that it could possibly be early signs of multiple sclerosis (MS). She had no symptoms and her examination was completely normal. Any comments on this person's fitness to dive?

Williams

She needs a proper diagnosis. In the UK they do not have enough magnetic resonance imaging (MRI) facilities to do scans on everyone who needs one. MRI is the diagnostic test which would be done in Australia. Without that one could not say anything about what it was. It might have been nothing. With CTs 5% of normal people show something which might be a small scar. MRI them and the vast majority have nothing at all wrong with them. If MRI was normal you would let her dive.

Bove

Over 50% of the underlying causes of total hemi-corporal paraesthesias are factitious or hysterical. There are very few neurological syndromes that would produce paraesthesia to the entire left half of the body. Many of these patients have psycho-somatic problems.

Unidentified speaker

A diagnosis is only worth making if it is going to change your management. A psychogenic disease in this woman was the thing that sprang immediately to mind, which to me would be a greater risk to her diving, perhaps than MS. MS, if it were present, does not cause sudden onset of vertigo, does not cause sudden onset of epilepsy or any of the other things that might cause a sudden catastrophic disaster in the water. One would need to advise her about the potential for these things developing. But I think it is her psychiatric risk which would be the flag that I would raise rather than her organic risk, and I would not do an MRI scan.

Myringoplasty

Meehan

A thirty one year old British male in retail sales. He had a history of a direct blow to the head in 1987 which resulted in a perforated ear drum on the right. He had myringoplasty done but this resulted in a dislocated incus, tinnitus and hearing loss in that ear. His left ear drum was perforated as a child and was repaired in 1984 at age 20 with some resulting minor hearing loss in that ear. On examination his Rhinne for right ear bone conduction was greater than the left, as expected. Both ear drums were mobile and equalisation occurred easily with Valsalva. The tympanogram was relatively normal in the left ear and an unusual shape in the right ear. Audiometry was not done. Any comments on this gentleman's fitness to dive, or problems he could have with diving?

Molvaer

I come from Norway and I am an ENT specialist and I see most Norwegian divers with ear problems sooner or later. I never do tympanograms myself. I look into their ears through the microscope while they attempt to equalise. If the drum moves I would let him try to dive. I would ask if he had trouble while flying and even if the ear drums have scars, if he could equalise easily I would let him dive. Where I work I have ample access to pressure chambers, so I could follow the man to one or two metres in the pressure chamber and look at the ear drum to see what happened. That will not be available in most doctors' offices, but I would let him try diving if he can equalise.

Meehan

He did go diving. My main worry was that because the right tympanogram was a little unusual that he could have a pressure related problem in his right ear.

Cognitive problems

Meehan

Just to show the sort of people that we do get in Cairns who want to dive. A fifty three year old American male who was retired. Six years ago he had a head injury, with back, neck and right hip damage and had some subsequent cognitive problems. Because of this he was on an invalid pension. He had bilateral hearing defects. He had radial keratotomy three years ago and was told by the specialist that he could dive after six months. He had peptic ulcer fifteen years ago and now takes amitryptyline and intermittent cimetidine. Other problems were bilateral arthritis in both shoulders from recurrent dislocations and spastic colon, which produced chronic diarrhoea if he did not eat properly. He was very keen on being passed fit to dive.

My opinion was that if he was able to be on an invalid pension, on the basis of cognitive problems following his head injury, he probably was not fit to dive.

Bove

You are assuming that divers have a certain level of cognitive ability, (laughter) and I am not sure that is a really good reason to exclude divers. I know there are people like this diving and I do not think there is anything there that would complicate his diving, so one is still stuck with no data to make a decision on. There are a lot of people with shoulder arthritis who dive so I would not exclude him for that. In the United States probably every other person takes cimetidine so one cannot exclude him for that. So we are down to the hearing defects, radial keratotomy and the amitryptyline and why he was on it. I do not think there is anything else that would complicate his life as a diver. There are a lot of people with one or another of these disorders who dive and they seem to get along fine. I am not sure any of these things are issues that would complicate his diving. Being on amitryptyline suggests that he has a bad depression disorder which might be of some concern.

Spinal surgery

Meehan

A twenty seven year old Australian beauty therapist had a repair to a right thoracic left lumbar idiopathic scoliosis done in 1993. The specialist who performed the operation had given her a certificate to say that the operation was successful and that the bone had undergone consolidation. He wrote that there was no contraindication to diving. On examination she had a vertical scar at the back from the repair as well as a thoracotomy scar where one rib had been removed as part of the correction procedure, and that rib had been used as a bone graft.

Veale

There are two theoretical considerations here. One is the potential for osteonecrosis, both within the graft and the residual donor area, through scarring and reduced perfusion. I think that is theoretical and unlikely to kill her or harm her too much. The big problem with any chest wall disorder is the exercise capability. Before being able to offer her advice I would need to know what her lung function was and her exercise capability.

Meehan

Her spirometry was completely normal. Exercise was not assessed because she did not do the swim test. Any comments on the thoracotomy scar or the risk of plural scarring with the removing of the rib?

Veale

Many surgeons will try to do this extra-pleurally rather than opening the pleural space, but sometimes that is not possible. It comes back to the question, is there a real risk, and if the risk is indeed plural adhesions between the non-operated upon lung and the chest wall, I would imagine one third of the people here have had pleurisy in the past and perhaps should not dive.

Meehan

It is very difficult in Queensland because the Code of Practice does call up the Australian Standard and so we are compelled by law to follow that Australian standard. It says that any open chest surgery is an absolute contraindication to scuba diving.

Hearing loss and migraine

Meehan

A twenty seven year old British female management consultant, with bilateral congenital hearing defects. She had a hearing aid for her left ear which she did not use. She had a history of migraines, particularly with stress, but she had no focal neurological symptoms nor vomiting with these. She had a history of blackouts, which had been fully investigated in the past, which had been put down to psychological cause. She had had a chest infection seven years ago, and had been prescribed salbutamol for a persistent cough which she had after that and she also had a history of anorexia nervosa. Examination, her Rhinne was normal and her Weber was louder in the right. Any comments on how you would address her problems?

Molvær

I would have liked to see the audiogram, but apart from that, having to use a hearing aid does not mean the hearing has to be very poor because some doctors give hearing aids for rather small hearing defects. On the other hand, if the hearing in one ear is very poor I warn the patient or diver or student and explain that a barotrauma to the other ear may put him or her in a very difficult situation, but I leave it to them to choose. As far as commercial divers go, which I mostly do, I would fail.

Bove

I have seen patients who have had migraines associated with exercise who have actually been disabled. They have had clear cut onset of fairly severe neurological symptoms. Anybody who has that kind of a migraine should be prohibited from diving because diving will often be a trigger. The more interesting thing about this woman is the fact that she has migraines, she has a history of blackouts that were possibly psychologically related and a history of anorexia. This is not the kind of person who usually wants to go diving. Has she been driven to it by a companion, or is there some other reason for it? My guess is that this woman would have trouble with the whole environment of diving. I would be concerned about the migraine, particularly if it is triggered by stress or exercise because that can be pretty disabling.

Meehan

She actually had borderline hearing loss where she could cope quite well without using her hearing aid. After a discussion of the risks of middle ear barotrauma and the fact that it is usually the most common barotrauma she decided that she did not want to dive.

Tricyclic antidepressants

Meehan

A 29 year old male Australian electrician was on prothiaden, which is a tricyclic antidepressant, 150 mg at night, to control excessive sweating. He was very conscious of his sweating and did not want to stop the prothiaden but did want to scuba dive. Any comments about scuba diving while taking antidepressants?

Gorman

Andy Veale told me about a lady, on monamine oxidase inhibitors, who was on a live-aboard dive charter, ate some cheese and became decerebrate!

Bove

Many people take tricyclic antidepressants for a variety of reasons and there is no particular interaction with the diving environment. More important is the underlying process that requires the use of the drug. I have never heard of them being used for excess sweating, but I do not think it would be a problem with diving. The tricyclics sometimes produce premature ventricular contractions. Occasionally I see a patient with extra beats that are not understood, they are induced by the tricyclics. The cure is to get them off the tricyclics or lower the dose.

Davies

I think he was on prothiaden not to stop his sweating, but to stop him worrying about his sweating.

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FITNESS AND THE OLDER DIVER

Sue Paton
with audience participation

Key Words

Air embolus, cardiac conditions, diving medicals, investigations, medical standards, pulmonary barotrauma.

Introduction

Paton

During this session we want to formulate some guidelines for assessing fitness to dive in the older diver.

We should also define the age of the "older" diver, but let us begin by assuming they would be fifty plus.

The diver

Consider the case of a 59 year old retired factory manager seen by you for the first time for a diving medical for recreational scuba certification. Two years ago in Fiji he did a resort dive and is still occasionally snorkelling and surfing. He used to play competitive squash but now his main exercise is walking. He has no allergies, is a non-smoker and takes no medicines. He has had excellent health in the past.

The medical

On examination there is no abnormality except that he weighs 91 kg. At a height of 174 cm, this gives him a body mass index of 31. His ideal weight would be less than 70 kg. His blood pressure is 140/90 sitting and his resting pulse is 80. He has no difficulty in performing a sharpened Romberg for 70 seconds.

He has an entirely normal resting ECG, performed immediately after a limited step test, up and down for five minutes on a step of 30 cm. His pulse rate is 100 one minute after the step test, at the start of the ECG, and back to his resting pulse rate of 80 at the end, a minute later.

Hold up you hand if you would have failed him? (No hands went up)

Exercise ECG

Unidentified speaker

Any form of exercise resulting in a pulse rate of 80-100 is not exercise. There is a resting ECG and an exercise ECG, what is the point of the in-between ECG? He is overweight. He has worked an executive type job. He has not been active in recent times. I think he should have a stress test.

Paton

According to the current Australian Standard for recreational dive medicals (AS4005.1-1992) there is no requirement at any age for even a resting ECG let alone a stress ECG. Are our guidelines satisfactory?

Bove

As a physician for a 59 year old who has not seen a doctor in a long time, one has other obligations besides just making sure he is fit to dive. I think you need to do rectal and prostate examinations, because two of his high risks are colon cancer and prostate cancer, despite the fact that he came into your office for a diving medical.

Paton

In Australia one would recommend that these tests be done by his own general practitioner, as these have no immediate bearing on his fitness to dive.

Knight

The Standard is a consensus document. We had a lot of difficulty getting the diving instructor organisations to agree to a medical at all. If doctors are going to investigate everybody, so that it appears that doctors are making a fortune from the medical, we will lose the support that we have got to keep the medical in the Standard.

This man did not complain of shortness of breath on exertion and in the Standard the only mention of ECG or exercise ECGs is in reference to there being doubt about the candidate's cardiac fitness for exercise. One needs some evidence of inability to exercise before being in doubt about the ability to exercise. If being overweight and over 50 was evidence of inability to exercise many people in this room would require an exercise ECG. We have already said that he meets the Standard. That is all that is legally needed for a diving medical in the states of Australia that require a diving medical to be performed to this standard.

I would do a British Army Step Test,[1] stepping, at a rate of 30 times a minute, onto a height of 17 inches (43 cm) for five minutes, then 30 second pulse counts (P1, P2, P3) are taken at 1, 2 and 3 minutes after exercise. To pass the sum of P1, P2 and P3 must total 190 or less (the lower the better). I have done this on every diver I have examined. If they pass I can safely assume that they will tolerate 5 minutes of moderate exercise. If someone developed angina during the test, which never happened in the 20 years I was doing diving medicals, I would have given the patient glyceryl trinitrate sublingually, told him he was not fit to dive and arranged referral. For those who fail the test I recommend a training program before they start their course, during this, if they are going to get symptoms, they get symptoms not sudden death in the water.

The diving doctor should offer advice about how to cope with the common problems of diving, such as ears and mention the need for physical fitness. After that it is up to the patient to get any treatment required from his regular doctor.

Veale

I think the concept of fitness to dive is a nonsense which tends to be thought of as black or white, pass or fail. There are only relative degrees of unfitness and therefore AS4005.1 is a mistake. Our job is to attempt to stratify the risk to the patient so that he or she can make an informed decision. In order do that for this individual, a number of additional investigations are required over and above those in the Standard .

Bove

I think a regular exercise stress test is quite adequate for a man like this with a normal ECG, without hypertrophy or bundle branch block. One can then interpret the stress ECG in a 59 year old as being indicative of ischaemia if it is positive and if it is negative, though it may not rule out coronary disease completely, it will rule out currently critical lesions that would get him into trouble when exercising. If it were strongly positive I would refer him to a cardiologist and let them decide what they wanted to do but I would not let him dive.

Barham

I think one has a duty of care to the patient to explain the risk of diving to the individual and in this case the main problem is going to be one of cardiovascular fitness. I think one should suggest an exercise ECG but if the patient declined and was aware of the risks, I would pass him.

Davis

Unfortunately exercise stress tests are conducted running on a treadmill or pedalling on a bicycle. Some people have no leg strength but they have got upper body strength. They could swim for 10 miles but could not run or cycle 100 m to save their lives.

Paton

Is it not appropriate to test a person's fitness using the intended form of exercise, therefore swimming in the case of diving? Des Gorman talked about fitting the test to the actual task.[2]

Unidentified speaker

I think we are missing the fundamental principle of the exercise stress test. When doing an exercise stress test for cardiac ischaemia, one is looking for an adequate heart rate response. Someone with weak legs will still achieve a diagnostic heart rate response at a lower work load, so one can still make an assessment for the presence or absence of ischaemia. If people have to do a mandatory swim test that is probably a more appropriate work load with which to test them.

Unidentified speaker

It is important to remember that one's VO_2 max on a treadmill or a bicycle ergometer is higher than VO_2 max when swimming. So a stress test on the surface in controlled circumstances is perfectly valid and more sensitive than doing a test in water. It is certainly safer if a myocardial infarct were to occur.

Paton

Hands up those who would pass him now. (Three hands went up)

That is a complete change from your earlier attitude. It seems that people have become aware of the risks of cardiac disease in older and overweight people

Chest X rays

Paton

Is there any reason for doing a chest X-ray?

Unidentified Speaker

Chest X-ray to assess cardiac size is a waste of time. Some people who have large cardiac silhouettes on X-ray have normal hearts on echocardiography and vice versa. And there can be significant left ventricular hypertrophy despite a normal chest X-ray.

Bove

I would not do a chest X-ray unless there was a history of pulmonary problems such as pneumothorax, recurrent pneumonia or a gunshot wound to the chest. The chest X-ray is too crude to use to assess cardiac size. If there was something not detectable by physical examination which had a high probability of complicating diving, then a chest X-ray would be necessary for all divers. Chest X-rays are not much help because most of the conditions that would complicate diving, without the clue of a positive history, are rare.

Veale

The first chest X-ray I ever did on a diver showed a pulmonary cyst. It totally coloured my practice of medicine for years and I have never found another.

Other Tests

Paton

Are there any other tests that you would like to do on this individual?

Knight

I would want to see how long he took to swim 200 metres. If he can cope with the swim he will be able to cope with the workload of learning to dive. That is a much more useful test than further medical investigations. In Australia every diving candidate must perform a timed distance swim supervised by a diving instructor. If they achieve this within the required the time, they have proved that they can tolerate the physical workload in the course. If they take too long, they should be told that they are not fit enough to manage the course.

Greg Leslie

You could just walk people up steps to make their assessment.

Unidentified speaker

I think it is very relevant that potential divers should be subjected to a test with reference to diving, like swimming. I noticed with some alarm that in December 1994 PADI removed the time factor in the swim test for instructors. This was the main physical test that a prospective instructor had to do apart from the routine medical.

Richardson

They still have to swim 800 metres in 17 minutes to become a dive master. When they go to instructor qualification they have to complete the distance but the time is not relevant. The 800 metre snorkel swim is to measure stamina but that is done before they go to their instructor development process. Their physical stamina is measured in many different ways as they progress. There is no under performance allowed, some folk use adapted techniques depending on their physical disability but they still have to meet the criteria for timed exercises. Most candidates for the instructor examination have met the criteria recently in their dive master tests as it is common to progress quickly from one to the next. Therefore we already have a record of the fact that they have met that time criterion.

Holiday tomorrow

Paton

Ideally to assess this individual's fitness and safety to dive he should have a stress ECG and his cholesterol measured.

These, however, are beyond the absolute requirement of AS4005.1. If due to the additional cost or time constraints, the individual is reluctant to proceed with your recommendation for these further assessments, is it reasonable to then counsel him about his possible cardiovascular risk, allow him to make an informed decision regarding this risk, and then, if he still wishes, pass him with a strong warning? Take into consideration an additional problem which arises in large metropolitan centres. If someone rejects your advice he can go around the corner, perhaps not in this situation, but in other situations, having learnt from your medical how to present to the next doctor.

Unidentified speaker

We should not sit on the fence. One's duty to the patient is to tell him that he should not dive without an exercise ECG.

John Parker

We see this scenario in North Queensland. Someone who wants to start a diving course tomorrow comes for a diving medical and the pressure is on to say yes or no. I have totally changed my views recently and it is not my problem any more, it is their problem. I do not think we should be intimidated. One has got to keep one's professional standards. One has got to go through the right processes and considerations. One really has to say, "No, you should not dive until these other things are sorted out."

Paton

I agree with what you say. But if you say, " I believe that at 59, overweight with borderline blood pressure, you are potentially at significant cardiovascular risk. You should have these tests done before I can say, from all discernible factors, you are genuinely medically safe to dive." And then he says, "I have already done a resort dive, I was fine. I want to do this. I am the one taking the risk." How does one respond?

Parker

One can sort that out by full discussion. These people have come to me for a medical opinion, so I am not deciding whether they should dive or not. They have come to me to decide if they are medically fit to dive.

Physical Fitness

Coetsee

Are you not confusing physical fitness and abnormalities? Is the diving medical not to detect medical abnormalities and is physical fitness an abnormality? A person can pass a fitness test and a month later be totally unfit again. I think this is a very big problem with divers. They do their course to become fit, they dive properly, they enjoy their dives on that course and then they go home. Six months later they want to dive straight away without getting fit again. Should they then be tested again? I think the physical fitness aspect belongs to the instructors and diving clubs. It would be ideal if SPUMS could introduce some form of physical fitness standard with which people should comply before they dive.

Bove

I do not think that we are arguing about physical fitness, we are arguing about his probability of having significant coronary artery disease which might lead to a tragedy while diving.

Paton

Should we not institute a program of regular check ups for the older diver who is at risk from ischaemic heart disease, advancing years, putting on weight and becoming less aerobically fit?

Unidentified speaker

I wonder how many people in the audience have a body mass index over about 28 and age over about 50 and how many of them have had an exercise stress test.

Leslie

I have a body mass index over 28 and have not had an exercise stress test but I can still run 16 km and swim 3 km.

Paton

In New South Wales there is no requirement for any training for doctors doing diving medicals. Any doctor should be able to work out a reasonable assessment of someone's cardiovascular fitness but perhaps physicians who are not trained in diving medicine are unaware of the need for sudden exertion when diving. Should the Standard have any firm guidelines to make stress ECGs mandatory after a certain age, as they are for the occupational diver?

Veale

We are in danger of going over the top here. The dive industry is already alienated from doctors. Intending divers, and certainly existing divers, have become deceitful, they conceal things. To have cut offs is totally artificial. Is 39.5 functionally any different from 40.5? We know that a cholesterol of 5.9 is better than one of 6.1 but does it justify vast amounts of screening? The cost per case detected has to be considered. I think that the absolutely critical thing here is that we have divers on our side. Fundamentally, divers are honest and should be just like any other patient. Diving is a action that patients undertake, just like driving a car, so that their family needs to have an awareness of their diving. I do not think that we can take over total responsibility for the diver, I do not think it is practicable. I think it is too expensive and will alienate the dive industry.

Reality

Unidentified speaker

Could the cardiologists tell us what the chances are of a fat 59 year old, in the normal course of his life, having a fatal accident while he is swimming? Most fat 59 year olds survive to be fat 60 year olds.

Bove

The probability of having significant coronary disease at age 59 is certainly increased and relates to the number of risk factors for the individual. With one risk factor the probability may be 1.2 times the non-risk population. With all the risk factors, hypertension, diabetes, smoking, obesity and hyperlipidaemia, the risk of coronary disease is 5 to 6 times the normal population. The best way to assess a 59 year old is look at their risk factors and tell the individual that because of these he may be between 1.2 and 6 times more likely to have coronary disease than somebody without risk factors. Whether this relates to the risk of sudden death or not, is a different thing because we cannot tell from risk factors whether an individual will have a sudden death while in the water. I would also say that if the same person came to you and said, "Can I play tennis?" you would have to go through the same discussion. One is concerned with sudden death from coronary disease.

Unidentified speaker

I would like to ask our dive organiser what would you do if this man arrived here to do a diving course which did not require a medical?

Unidentified Instructor

I think people are losing the point. We are talking about sport diving. As instructors we qualify divers but we also recommend limitations. Not every diver would be suitable for every dive. I think the man who does one "Discover Scuba" dive in 6 m of water on a sand bottom, is probably at no more physical risk than if he plays tennis. We certify a lot of people, but our job is not just to certify them, it is also to give them the recommendations about where and what their limitations should be. I think they are looking to your profession for the same advice. If a diver's physical health and fitness may preclude them from diving safely, recommend further action rather than simply telling them not to dive. If someone is going to have a cardiac arrest underwater he might just as easily have it on the tennis court or somewhere else. Perhaps the 6 m swim around dive is going to relax him a lot more than if he gets dragged behind a ski boat. It is all relevant because we are talking about sport diving. I wonder how any people here would be diving if we said that you have to have a medical before you can come diving with us. We have had enough trouble to get liability forms from you. (Applause)

Bove

As a physician I have no coercive powers. All I can do is provide advice to the individual about what is and is not safe. I can tell a late stage diabetic with retinal detachments in one eye and one leg missing and gastroparesis that I think it would be very risky to go diving but I cannot say "You are not allowed to dive". All I can do is provide what I think is reasonable advice based on my assessment whether it is safe to dive or not. If it is not safe to dive what are the alternatives? Can something be fixed after which it will be safe to dive? I would never let somebody dive after a spontaneous pneumothorax, even after they had a pleurectomy. I think it is just too dangerous. That same person can go to another doctor, lie about the spontaneous pneumothorax and get certified and go diving until he gets a pneumothorax. It is different in the military where the military system excludes people who fail the medical from diving. It should be well documented in your records that you have advised the individual that it was not safe or that certain things needed to be done, and in extreme cases have a patient sign the note on the chart stating that he read and understood your advice.

Veale

I think we have created a problem for ourselves by creating a black and white standard. A pass or fail standard. There is no fitness to dive, there is no safe diving. There are relative degrees of everything. This is an informed consent issue. Surely we can talk to patients about their relative risk. The purpose of tests is to help clarify the risks for us, so that we can better present them to the patient, but it still is and should be an informed consent issue.

Tony Slark

We seem to be overwhelmed by the need to assess somebody's fitness to use apparatus underwater. Where there are potential medical disorders that we can assess by age, blood pressure and so on, or there are obvious reasons why somebody is apparently physically unfit, we should advise them to buy a snorkel, fins and a mask with which to enjoy the water sensibly and get fitter and familiar with the marine environment before they advance to using scuba apparatus.

The decision

Paton

In fact, this man had already been snorkelling with his wife on all their holidays, and while she had no intention to take up diving, he was quite vehement about his desire to dive. Having discussed his risks with him at great length so that he truly understood the risks, I passed him, writing all the warnings on the certificate with my strong recommendation that he must pass the 200 metre swim test in 15 m, to dive only in tropical waters, which was his stated intent, and not to dive in Sydney in winter, in surf or swell, and left him to make his own informed decision.

The seventh dive

He took the decision to dive and undertook a course in Sydney in summer. He was part of a group of 7, everyone else in the group was younger and probably fitter than him. On the last day of his course he did his 6th dive, (including the resort dive he had done), to 18 m for 23 minutes. On the next dive, which was his final certification dive, he experienced difficulty, as on his previous dives, with buoyancy control, probably because he was wearing 13.5 kg (30 lb) on his weight belt. He had problems descending and ascended briefly before continuing the dive, but then the rest of the dive was uneventful. Towards the end of the dive, one of the other students was low on air, so the group ascended with the instructor, all holding hands, supposedly a very controlled ascent. When they got to the surface they began swimming to shore. After 20 m he complained to his instructor that he was feeling tired. His instructor began to tow him, initially linked arm in arm and then on his back, towing him by his tank valve for another 60 m. The instructor then noticed that he had become unresponsive to conversation although his eyes were open. The instructor found he was pulseless and not breathing and began in-water expired air resuscitation while help was summoned. He was carried the last 20 m to the beach where the paramedics continued the resuscitation attempt. At the nearby hospital he was pronounced dead 1 hour and 52 minutes after he had surfaced from the dive. The Sydney Police Diving Squad examined all the scuba diving equipment and found it in working order.

The diagnosis

Paton

An infarct is one possible cause of death. What other causes should be considered?

Unidentified speaker

Any illness that effects a diver must be assumed to be diving related until proven otherwise. He had just come to the surface so my diagnosis would be air embolism. Only a post mortem would tell.

Paton

At post mortem there was blood around the nose and the mouth, the ear drums were intact and there was no subcutaneous emphysema. His heart weighed 420 grams. His left ventricle was mildly dilated to 45 mm in diameter. His intraventricular septum and lateral wall were 12 mm in thickness. He had normal valves. Atrial and ventricular septa were intact and there was no scarring. The four major coronary vessels had up to 30% stenosis by atherosclerosis. His upper airways contained blood stained fluid. There were oral bacteria and food particles around the bronchi, prominent pulmonary oedema and intra-alveolar haemorrhage. He had a fatty liver, erosions and congestions of the cardio-oesophageal junction, with two 5 mm long tears in the gastric mucosa and 100 ml of heavily bloodstained fluid in the stomach. His kidneys were normal size with focal segmental scarring and hypertensive vessel changes. Chest X-ray revealed gas in the right ventricle, the arch of the aorta, neck vessels and the pulmonary veins. Opening the scalp under water revealed air in some of the scalp vessels. There was also air in the vessels of the brain and gas in the left ventricle on aspiration. He had small apical bullae but no pneumothorax. The pathologist could not tell exactly where the gas came from.

Bove

Most air emboli have neurological symptoms and unconsciousness but rarely a cardiac arrest. Tom Neuman and I are writing a paper on cardiac arrest in the presence of air embolus. In every case that we have collected there has been a total replacement of the central circulation with air.

Paton

Why did he embolise?

Unidentified speaker

He had a very unsafe profile. We have been told that he had difficulty with buoyancy, that he had 13.5 kg (30 lb) of lead and that he had difficulty descending. I cannot believe that a group of divers all holding hands can control their buoyancy. Each diver needs a free hand to adjust his or her buoyancy compensator. When holding hands it is inevitable that they will make an uncontrolled and possible rapid ascent. It is likely that he held his breath for a moment too long.

Veale

Alveolar over distension or lung over distension rather than the pressure changes are the likely cause of pulmonary barotrauma. This man may have been a bit panicky, he was certainly breathing at close to TLC (total lung capacity) in order to compensate for his 13.5 kg (30 lb) of lead, so operating in the absolute upper range of his volume compliance curve. That with an uncontrolled ascent and breath hold would have easily caused the air embolus.

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SPUMS ANNUAL SCIENTIFIC MEETING 1996

"TECHNICAL" DIVING AND DIVER PERFORMANCE: A PERSONAL PERSPECTIVE

Michael Davis

Key Words

Mixed gas, nitrogen narcosis, performance, rebreathing.

Introduction

Whatever the nature of the diving activity being undertaken, whether it is a sport scuba shore dive in perfect, balmy tropical, conditions or a saturation diving operation, like recovering the gold from HMS Edinburgh above the Arctic Circle, in its planning the same broad principles always apply (Table 1). As an example of the increasing complexity that a particular task underwater may require I shall use as an historical example my own introduction to "technical diving" over 30 years ago as an undergraduate student in a university British Sub-Aqua Club (BS-AC) branch in England.[1] I hope that describing this project will, in the process, identify many of the important challenges to be met in the transition from open circuit scuba-air to mixed gas semi-closed rebreather diving, thus providing a reference point during the conference. At the same time I wish to make a few comments about the efficiency of divers underwater, again largely using historical data from diving experiments in the 1960s and 1970s in which I or close colleagues took part.

Dive planning

It is a truism that the most important component of dive planning is to define the **Purpose(s)** of the dive(s) (Table 1). If the complexity or risks of a particular dive are greater then, on a risk/benefit basis, the justification for doing it must be stronger. Therefore, clear goals should be set and these determine the choice of diving techniques to be used, selecting and training of a diving team and so on.

The purpose of Nic Flemming's project was to study the physical structure of sand ribbons in the English Channel several miles offshore at a depth of 40-60 m. We initially attempted this in 1964 on scuba-air, but the working conditions underwater so reduced the intellectual ability of the divers that several experiments had to be abandoned. Such an outcome was probably predictable, but at least led to a careful review of how the scientific goals might better be achieved.

The decision was made to move to oxygen-helium (heliox) mixtures. This had the secondary effect of broadening the scope of the planned diving and the initial phase, run in the Mediterranean, constituted the first ever open-water studies on diver performance comparing air and heliox.

TABLE 1

DIVE PLANNING

PURPOSE
Defining the purpose of the diving determines:

Techniques
Scuba / SDBA / Rebreathers / Bell / Saturation
Personnel:
Personalities / Experience / Expertise / Motivation / Team Size
Equipment and Gas Mixes
Purchasing / Preparation / Maintenance
Training
Equipment / Diving techniques and procedures
Planning
Dive program(procedures / decompression) / Support infrastructure / Emergencies
Execution
Diving / Weather / The Unexpected
Outcome
Was the original purpose achieved?
What were the health and financial costs?

TECHNIQUES, EQUIPMENT AND GAS MIXTURES

The upshot of this was the assembly, by the Admiralty Experimental Diving Unit (AEDU), of a semi-closed rebreather of sufficient capacity for 75/25 helium-oxygen diving to 70 m. This was made by attaching two 50 cu ft. SABA (Swimmer's air breathing apparatus) cylinders for the heliox mix through a second fixed flow rate reducer (set at 32 l/min) to a CDBA (Clearance diver's breathing apparatus) counterlung with a separate oxygen supply. It was not until several years later that those of us taking part fully appreciated just how much of a prototype this set was and that we were, in fact, trialling the Royal Navy's first ever such equipment for them!

PERSONNEL AND TRAINING

Selecting the size and make up of the dive team largely came down to those undergraduate club members with enough time and money to take part in the winter training and five weeks of diving during the summer vacation. Of the eight-man team only two had more than two years' diving experience and two divers had never dived deeper than 30 m before.

Theory training was based on the RN and USN Diving Manuals, group discussions and the exciting intellectual stimulus of talking with such people as Drs Hempleman, Barnard and Elliott at the Royal Naval Physiological Laboratory (RNPL) in Alverstoke. Initial practical training on the operation and maintenance of the set was conducted at AEDU though, in retrospect, this was very limited, with each diver doing only one to four hours on the set before commencing deep open water dives!

The proposed decompression procedures for a bottom time of 15 minutes at depths of 30, 45 and 60 m were tested at RNPL. The empirical nature of developing tables was brought home strongly to us by the way in which our planned stops were changed firstly following two bends during the chamber dives at RNPL and then later after the Navy's first unsatisfactory open water experiences with their heliox tables deeper than 60 m shortly before our summer season of diving (Table 2).

In practice then, team selection was based largely on happenstance and enthusiasm, training was minimal by modern standards and the decompression tables were essentially untested!

PLANNING AND EXECUTION

The conduct of the diving program was described in detail by Flemming.[1] As this publication is difficult to obtain I am willing to supply copies on request. In summary, despite our limited training, no operational problems arose with the heliox set either during the performance studies conducted in Malta, nor during the geological diving off Plymouth. The amount of preparatory work for each dive was considerable and seven men were actively engaged in its conduct each time. The only problem we encountered was that the capacity of the twin 65 cu ft open circuit air set was sometimes insufficient for the 60 m dives, requiring staging of extra cylinders for decompression. The decompressions for the air and heliox dives to the same depth and time were very different (Table 2).

That one cannot plan for every eventuality was exemplified by three totally unexpected problems. Several of the heliox storage cylinders were delivered with slow leaks, seriously reducing the amount of mix available in Malta. Then the project leader's wife, who was with us, required major emergency surgery in the middle of the Malta dive program. Finally, a road accident in Italy on the way back for the English Channel diving leg, destroyed one of the semi-closed sets though, fortuitously, not the car occupants.

OUTCOME

Using heliox in the English Channel resulted in our achieving as much in one week's diving as we had in a month on air. Interestingly, the geomorphology project was, in fact, finally completed a few years later using a submersible! The diver performance studies provided valuable data[2] and raised issues regarding the relationship between narcosis and performance for much further research.[3]

Diver performance

The disparate techniques embodied in the nebulous term "Tek Diving" take us into a different range of risk-benefit and cost-benefit decision making than that for open-

TABLE 2

The decompression schedules for air and 75/25 heliox for a 15 min bottom time at 60 metres. The first heliox column is the planned profile, and the second the actual profile used for the dives. Gas mix for each stop is shown.

Depth	Air dive stops		Heliox **(planned)** stops		Heliox **(actual)** stops	
m	Minutes	Breathing gas	Minutes	Breathing gas	Minutes	Breathing gas
18	-		3	HeO_2	5	HeO_2
15			3	HeO_2	5	HeO_2
12			3	HeO_2	5	HeO_2
9	5	Air	3	O_2	10	O_2
6	5	Air	6	O_2	10	O_2
3	20	Air	15	O_2	20	O_2
Total decompression time	30		33		55	

circuit scuba-air diving to 40 m. The increasing demand for these techniques is because, in the simplest terms, tekkies want to dive longer, deeper, more safely and more easily.

The last, more easily, is summed up by Flemming's comment on heliox use in the English Channel.[1] "The impression of clarity of vision and thought was so startling that it was almost like seeing the sea floor for the first time." I wish to focus on one aspect of making it easier by briefly discussing nitrogen narcosis and its relationship to the wider concept of diver performance.

When people are required to work under conditions which deviate from the biological norm, such as underwater, they may be said to be operating under stress.[3] Whether these stresses improve or impair performance will depend on the type and degree of the stress(es) and the nature of the task(s). In diving the interactions are obviously complex and difficult to control, making the outcome unpredictable.

Experiments over the past 40 years have attempted to study the independent impact of such factors as nitrogen narcosis,[3,4] cold,[5] spatial perception,[6] drug interactions,[7] gas mixes[8] etc., and then to consider the results observed, whether derived from simulated dives in a chamber or underwater experiments, in relation to open-sea conditions where the whole gamut of factors operate simultaneously. Conversely, many different tasks have been tested, from simple isolated manual or intellectual tasks, often employed in batteries of tests[8,9] to complex sub-sea structure assembly employing the interaction of several divers,[10] in order to understand better how divers function underwater.

What has emerged is a realisation that there are wide differences in the susceptibility of different tasks to the effects of various stresses, and that the final interaction of diver, environment and task varies considerably. What does that all mean? Simply, that what you achieve on a given dive might be as much in the lap of the gods as anything else! The concept of diver performance, then, is a complex entity influenced by many factors (Table 3).[11]

I will use nitrogen narcosis as an example of how this picture has been built up from various experiments, mainly those conducted or supervised in the 1960s and 70s by Professor Alan Baddeley, who has been one of the pioneers of field work on diver performance. For an extensive review of nitrogen narcosis the reader is referred to Fowler et al.[12]

Every novice diver knows about nitrogen narcosis, Jacques Cousteau's "raptures of the deep", and how the brain is progressively impaired by increasing partial pressures of nitrogen with depth, the so-called Martini's Law! Nitrogen narcosis is written about in diving texts and taught to sports, commercial and military divers as the overriding factor far outweighing everything else in its effects on diving safety and efficiency for any diving beyond about 25 m. Therefore, avoidance of narcosis is listed amongst the main rationalisations behind the development of sport diving techniques other than scuba-air.

Yet how accurate is this picture? Take for instance the results for one simple manual dexterity task, transferring nuts and bolts from one set of holes in a metal plate to another set, which has been used widely in diving studies. Figure 1 summarises the data from six experiments. Graphs A and B show the change in performance in a dry recompression chamber for 75/25 heliox and air respectively. Essentially there is almost no deterioration to 60 m with heliox, but a significant, though small, fall with air at 30 m, demonstrating the narcotic potential of nitrogen.[12,13]

Now examine graphs E, F, G and H, taken from open water air diving studies in varying conditions. The two most striking features here are, firstly, the marked fall in performance simply with immersion in shallow warm water and, secondly, the variation in further performance decrement at 30 m depth.

TABLE 3

THE MAJOR FACTORS INFLUENCING THE PERFORMANCE OF DIVERS IN OPEN WATER CONDITIONS.

Physiological	Behavioural	Environmental
Inert gas narcosis	Training	"Immersion effect"
CO_2 retention	Experience	Reduced light
Hypothermia	Motivation (arousal)	Reduced visibility
Hypoxia	Anxiety	Weightlessness
Gas impurities	Reduced sensory input	Mechanical restriction
Drug interactions	(all modalities)	Water movement

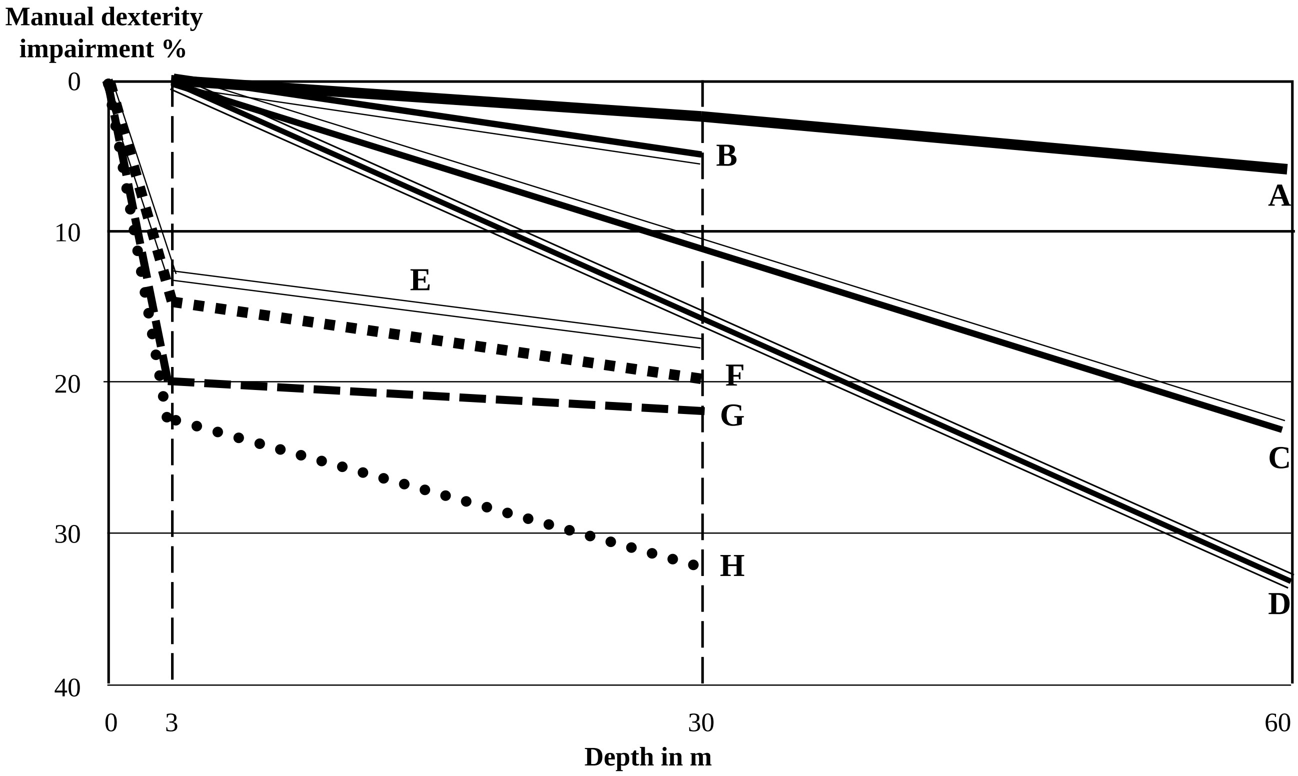

Figure 1. Change in performance of a manual dexterity test during simulated dives in a chamber (curves A and B) or in open water (all other curves) from six published studies.[11-14] See text for details. All data normalised and expressed as percentage change from the control condition (either dry land, curves E, F, G and H, or 3 m depth, curves A, B, C and D).

The "immersion effect" on performance has occurred in all published studies of manual performance where it has been looked for and is also present for some measures of intellectual performance such as aspects of memory. The implication of this for diving is that learned skills are often best performed in the conditions under which they were learnt. To turn that on its head and apply it to technical diving, tasks learnt in a swimming pool will not necessarily be properly recalled or performed under operational conditions. One must train divers in the skills they need **in the environment they will be exposed to**. In practice, of course, this is not always possible.

Why do the slopes of E, F, G and H in the water differ? Experiment H was performed at sea from a dive vessel in moderate diving conditions using, as subjects, relatively inexperienced divers, few of whom had dived to 30m before.[13] Experiment G was performed from a stone jetty in idyllic, calm, clear warm waters using divers used to much harsher conditions,[14] while Experiments E and F fell somewhere in the middle.[11]

Thus the performance decrement with depth reflects not only the effects of nitrogen narcosis itself but also an interaction of other factors believed to result in heightened anxiety in the diver.[3,11] Some of these factors are summarised in Table 3. Open water studies to test this hypothesis, looking at physiological variables and psychometric evaluation at the same time, have been inconclusive,[15] and this remains an area still requiring good research.

What then of the performance advantages under operational conditions of moving to a non-narcotic gas mixture such as 75/25 heliox at 60 m using semi-closed rebreathers? It can be clearly seen from graphs A, C and D that there is a significant deterioration in performance in open-sea conditions compared to a chamber environment *irrespective of the gas mixture used*.[2] In addition, divers generally performed worse at this depth on air than they did on heliox. However, this was *not* universally the case. Similar results were obtained during the US Navy Sea Lab II project, where performance at depth in the habitat was unimpaired while performance outside in the sea showed a marked deterioration.[16]

Conclusion

In this presentation I have briefly described my personal experiences on a diving project in the mid 1960s run by a group of postgraduate and undergraduate student members of a BS-AC branch using semi-closed rebreathers and heliox gas mixtures to depths of 60 m. This illustrated many of the general principles of dive planning and the specific challenges of so-called technical diving.

From this work an understanding evolved that impaired diver performance is not synonymous with nitrogen narcosis and that the latter is only one of many factors that come to play a part in determining the effectiveness of working divers, be they hunter, photographer, scientist or commercial diver.

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MENTAL FITNESS IN TECHNICAL DIVING FOR SPORT SCUBA DIVERS

Sonnhild Schiöberg-Schiegnitz

Summary

Technical diving requires not only elaborate technical equipment but the appropriate readiness to come to terms with the necessary technical basic knowledge. Technical diving requires a particularly high level of self-control mechanisms. An essential part of the examination for diving is assessment of emotional stability, reliability, capacity for self-control, intelligence and social behaviour. These are fundamental for safe diving. Mental training is one component of training designed to pre-program the brain's solution-paths and behaviour sequences by thinking them through repeatedly and practising repeatedly until they run reflexly in critical situations.

Keywords

Fitness to dive, mixed gases, performance, recreational, training.

Introduction

The main cause of diving accidents is human failure. Decompression sickness is a bodily organic illness but, in most cases, it is wrong human behaviour which is the triggering factor. There have been extensive studies of diving accidents triggered by human factor.

Technical diving poses particular demands on the sportsman's personality. Technical diving is not a spontaneous recreational activity, just for fun, but requires thoroughgoing theoretical knowledge and inner readiness to behave appropriately and react correctly to the technical conditions. The diving fitness examination must therefore involve an assessment of mental performance capability. This means not only the exclusion of psycho-pathological syndromes (psychoses, depressions etc.), but requires a differentiated assessment of emotional stability and capacity for self-control.

Accident prevention does not consist only of retrospective fault analysis but should include training in behaviour sequences which avoid or counter inappropriate actions. The objective of mental training is to pre-program thought sequences and establish these sequences as reflexes. Just as the optimum fin stroke can be achieved by practice, situation analysis and decision processes can also be practised. In problem situations information is provided from different memory stores and perception organs while solution paths are developed through a number of neuronal pathways and brain centres as testing and evaluation must take place, according to the principle of trial and error, before the final action plan is established. Finding a solution path requires many small individual steps. Repetition, and learning by example, can shorten solution finding. This makes neural pathways free again for spontaneous reflections. Decision processes which, in theory, run repeatedly via the different brain centres are stored in memory by practice via associative paths and run in practice as reflex.

Mental fitness in fitness for diving examinations

There are standardised suitability tests for professional and naval divers. The GUW (emotional dimensions under water) test was developed in the German-speaking area for sports divers in order to find indications of hazardous personality factors during the fitness for diving examination.[1]

The GUW test covers the following variables:
- Capacity to identify emotionally conditioned bodily reactions
- Ability to identify personal emotions
- Achievement motivation
- Readiness to take risk
- Diving addiction

One needs to assess to what extent the diver allows himself to be led by his emotions, without recognising the fact, and the chances of dangerous behaviour due to excessive achievement motivation and readiness to take risks. There are considerable problems in Germany with these factors as shown by repeated fatalities among sports divers in deep cold waters.

A decisive prerequisite in technical diving is a well-pronounced self-control function. Digman[2] has defined 5 basic qualities of the successful sports personality:
- social maturity and intelligence
- social activity and capacity to carry through a plan
- determination
- will to achieve and stamina
- self-control and stress-resistance.

If, in the course of the examination, a significant deficit comes to light in one of these areas, fitness to dive must, for the time being, be questioned.

Mental training as a part of diving training

There have been numerous investigations of the effectiveness of mental training in competitive sport. The objective of such a training is to achieve psychic stability, maximum physical performance and fighting spirit to the point of aggression, and in so doing, self doubt, anxiety and distractibility are reduced.[3,4]

In the case of sports diving there is a different objective. It is not maximum performance which is needed. Psychic stability and reduction of fear to are needed to avoid panic reactions. Inherent in diving are a multiplicity of fear-triggering factors arising from environmental conditions, the demands of technical equipment and the influence of altered gas partial pressures on brain performance. However also emotion-positive factors play a role such as thrill, self-satisfaction and a sense of achievement.

Behaviour control runs in accordance with underlying neuro-physiological function principles. Here three principles of functional disturbance can be differentiated:
- emotional flooding, when overactivity of the brain stem blocks cerebral activity;
- conscious fixation on a personal objective, when activity of one brain centre blocks input from other centres;
- excess of information, when simultaneous activation of too many brain centres impedes evaluation.

The brain has only a limited processing capacity. If neural activity is increased too much, further neural impulses cannot be processed. With mental training it is possible to reduce neuronal overexcitement and to extend receptive capacity by attention training.

In the case of sport divers all three disturbance models can be the cause of accidents. In the case of novice divers it is fear which is the ruling factor. Behaviour controlled by fear is characterised by affective overloading. The result of emotional flooding is overactivity of the fear and panic centres which restricts the running of logical thought processes in the cerebral cortex. Acheivement brings feelings of extreme well-being to the point of euphoria. Here overactivity of the pleasure and reward centres restricts logical thought processes in the cerebral cortex. When diving altered gas partial pressures directly influence the activity of neurotransmitters.

Another disturbance over-fixation on a personal objective. Attention is directed to a defined goal and all further information input is blocked off. This "tunnel vision" pattern of behaviour is shown by high achievement motivated persons, counter-phobic divers or depth-addicted divers. Attention is focused so the environmental signs and indications are not perceived.

The danger in technical diving is activation of too many information input systems so that excessive input impedes conscious processing. Technical diving does not allow freedom for spontaneous actions such as going a bit deeper because the wreck is so photogenic.

A decisive variable in mental training is the type of attention. Differentiation is based on the type of concentration. Fear, or behaviour controlled by depth addiction, is characterised by very narrowly bundled attention (focusing). There is a lack of insight for the reality of situation. Here the objective of training is a greater divergence of attention by incorporation of further information systems. Technical diving on the other hand requires a tight focusing on the specific dive plan.

Training content and objectives are designed in line with the different underlying mechanisms. Mental training nevertheless follows these basic steps:

1 Recognising a problem
2 Situation analysis
3 Decide on actions to deal with the problem
4 Action plan
5 Feedback

The most important step is recognising a problem. It may be emotional overloading, fear or euphoria, the hunt for subjects to photograph, or the urge to go deeper. To be able to act, one must first recognise the need for action. The aim of mental training is to avoid being surprised by a problem and to register approaching difficulties in advance. This allows the possibility of being able to take the necessary corrective action in good time.

The basic requirements for self-control are the regular checking of emotional state, autonomic nervous system function status, intellectual performance capability, technical data and comparison of how closely the actual dive corresponds with the plan. It also includes recognising possible indications of incipient nitrogen narcosis. As soon as a possible problem has been consciously perceived a diver should analyse the situation and evaluate whether an actual hazard is posed or behaviour correction needed.

Emotional stabilisation is always required before action. It is possible that relaxation techniques are required. Stabilisation also includes a conscious act of emotional self-control, if the current mood (fear, euphoria or indifference) is evaluated as being a source of danger.

After successful stabilisation comes the drafting of a problem-solving strategy. For this, reverse polarisation of the attention variables is required. Too narrow a focus, as in achievement oriented situations, must now be widened. Scattered attention must be concentrated on the problems.

After every action plan there is a feedback loop for assessing efficiency and after this possibly a modified plan.

A thorough training provides as wide a variation of different situations as possible. The greater the frequency of the exercise the shorter the feedback loop becomes as unnecessary trains of thought fall away. Practice results in memory storing, so when the situation occurs many thought sequences run automatically and unconsciously. In this way sufficient neural pathways remain clear to process current information effectively.

Conclusion

Technical diving does not contain any greater risk than traditional compressed air diving, as long as the diver is in command of the technology. A precondition for this is that he acquires the necessary theoretical knowledge and is prepared to conduct the dive in accordance with the technical requirements. A training model for training mental fitness is available. It remains to be seen to what extent commercial interests or safety aspects dictate the actual training of technical divers.

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