surgery. Another very useful tool is the impedance tympanometer for assessing the tympanic membrane, the ossicular chain and middle ear function.

Conclusion

There has been little information published on the results of sports diving medicals. By reviewing my last 1,000 sports diving medicals I have attempted to highlight interesting points, identify problems and shortfalls in medicals, with possible solutions and, hopefully, create further discussion on the needs of diving doctors and the diving industry. Only by showing how diving medicals help the diving industry will they become totally accepted and supported.

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PAPERS FROM THE SPUMS 1989 ANNUAL SCIENTIFIC MEETING

PROBLEMS WITH LESS THAN 2 ATA EXPOSURES

Jimmy How

Introduction

Diving and working in compressed air tunneling are similar in many respects. After noticing the 10 cases of decompression sickness (DCS) arising from compressed air work at less than 1 bar gauge pressure, it brings to mind that sports diving, even at shallow depths can carry risks of DCS. Aside from DCS, the commonest diving accidents and deaths that are seen in Singapore result from divers experiencing problems at shallow depths. I will discuss:

(a) DCS at shallow depths
(b) Medical problems in diving
(c) Diving in unfamiliar situations

Brief Historical Background

People have been diving for food, pearls, sponges for thousands of years. Divers have been known to be in existence during the time of the ancient Greeks and the Trojan War.

Breath-hold diving was the earliest form of diving that evolved. Breath-hold divers are still in abundance everywhere where shallow, calm and warm waters provide the recreational diver a chance to immerse himself amongst the abundant marine flora and fauna found in the tropical and subtropical regions of the world.

It is noteworthy that breath-hold diving for commercial gain still exists among the natives in the Pacific Islands and among certain traditional occupations in Japan and Korea.

Sports diving with self contained equipment only became popular after 1943 when Jacques-Yves Cousteau and Emile Gagnan developed the modern demand intake valve. Today, there are thousands of recreational divers who venture out into the sea daily. With the explosion of the sport in the 70s and the 80s, diving physicians are concerned about the safety of the medical selection and diving training provided by various diving operators. Inexperience among the new entrants to the sport and the overconfidence of the experienced diver have resulted in unnecessary fatalities.

Surface supply equipment is another method of diving commonly practiced. Many of the cases of decompression sickness treated in Singapore in the late 1970s and the early 1980s were fisherman divers suffering from DCS who had used surface supply equipment. Abalone divers in Australia use surface supply equipment. Based on our experience with the Singapore Mass Rapid Transit (MRT) Project, it may even be possible to suffer from DCS at shallow depths of less than 10 metres.

I will discuss the problems that may be encountered by the sports diver at less than 1 bar gauge (or 10 metres sea water) exposures and highlight certain diving related problems that can arise either through ignorance or overconfidence. But first I will discuss the 10 cases of DCS arising in compressed air workers during the MRT project.

Decompression sickness after less than 2 ATA exposures

Decompression sickness occurring at pressures of less than 1 bar gauge or (14.7 psig) is very unusual. A literature search revealed that probably only Behnke[1] has ever reported instances of cases of DCS at less than 1 bar gauge exposures for compressed air workers. In his report, he noted 9 cases of DCS occurring in less than 1 bar exposures of compressed air workers at the Bay Area Rapid Transit (BART) Project in San Francisco, California.

In conversation with other hyperbaric physicians, I have heard of other such cases here and there but I have been unable to trace any publications reporting these. Eric Kindwall mentioned to me 4 cases of DCS occurring at less than 1 bar gauge.

In the Singapore MRT Project, there were 10 confirmed cases of DCS at less than 1 bar gauge exposures. They all responded to recompression therapy with complete resolution of symptoms.

The tunnel projects were completed in record time and because of the haste in completing the projects, long working hours, sometimes exceeding the limits of the Blackpool Tables, were employed. This may have resulted in some of the DCS cases.

Analysis of Singapore cases of DCS

Eight cases of DCS, following exposures to below 1 bar gauge pressures, occurred at Contract 109 while the other two cases were seen in Contract 301. Seven of the cases occurred after exposure times of 12 or more hours (maximum 12 hours 22 minutes), including the time for decompression. The other 3 cases occurred after exposures of between 10 hours 45 minutes and 11 hours 45 minutes.

The lowest working pressure where DCS cases were reported, was 0.8 bar gauge while the highest was 0.95 bar gauge. One case was seen in a surveying assistant, and another was seen in a foreman. The rest of the cases occurred amongst compressed air workers (Table 1).

ENVIRONMENTAL FACTORS

During the exposure periods shown in Figure 1, tunnel temperatures were between 28 and 34 degrees centigrade with an average humidity range between 60% to 100%.

CLINICAL PRESENTATION

Pain was the commonest presentation noted. They were described as deep joint pains. Tenderness was present in one worker. Two workers complained of warmth. No swelling or rashes were seen. One worker had numbness around his joint. Table 2 shows the distribution of symptoms.

TREATMENT

All cases were treated with recompression therapy. Table 61 (oxygen table) was used in 50% of the cases. CIRIA 1 (air table) was used in 40% of the cases. CIRIA 1 and Table 62 were used in Case 9 when there was an initial lack of response to the CIRIA 1 table at depth. Complete relief of pain were recorded in all 10 cases (Table 3).

DISCUSSION

The cases manifested characteristic symptoms of DCS and responded to treatment. The 10 cases represented a DCS incidence of 0.005% of man decompressions for all pressures and 0.008% of man decompressions below 1 bar.

None of the men in this study was obese. The maximum percentage body fat was 20% and the minimum 6%. Average percentage body fat was 14.5%. Although obesity is recognised as more susceptible to DCS than thin people, there were only 27 obese persons (>24% body fat) in the Singapore MRT Project out of 1,737. This accounted for the bias of thin persons developing DCS. In addition, as the duration of exposure was limited for the obese persons, the likelihood of any of them getting DCS was reduced.

In our study, the oldest worker was a 39 year old foreman. With the exception of a survey assistant, the rest were compressed air workers. The youngest compressed air worker affected was 18 years old. The average age of those affected was 29.2 years. As the number of cases was small, we are unable to prove any correlation of DCS with age, obesity and type of work performed. However the cases occurred after very long exposures and the men were involved in heavy work. The long hours probably allowed for complete tissue saturation with nitrogen, even the very slow tissues, those tissues which take a very long time to become saturated with nitrogen.

Two cases worthy of mention were not treated by the Navy. These two compressed air workers completed their work in Singapore and were flying back to Bangkok, when they reportedly felt joint pains. These joint pains subsided when the plane finally landed in Bangkok.

Interviews with various Korean workers also revealed that 3 of them had developed joint pains after such exposures but they did not report this to their supervisors. Subsequent exposure to compressed air relieved their symptoms.

Possible mechanisms of DCS in less than 1 bar

It is uncertain what caused DCS in these 10 men. The tendency for bubbles to form is governed by the principles of fluid mechanics. It has been shown that a large force is required to form bubbles in vitro, unless bubble nuclei are present. These forces may be due to tribonucleation, cavitation or even from spontaneous in vivo nuclear fission. We feel the following mechanisms are likely to be implicated.

The compressed air workers were doing heavy work involving lifting and the use of vibrating tools. This can cause the formation of micronuclei by the process of tribonucleation. Tribonucleation is induced in vivo when two

TABLE 1

DECOMPRESSION SICKNESS (DCS) AT LESS THAN 1 BAR PRESSURES IN RELATION TO RACE, CATEGORY OF WORKER, BODY FAT, AGE, WORKING PRESSURE AND TIME OF ONSET OF SYMPTOMS.

S/No	Case	Race	Contract	Type of Worker	% Body Fat	Age	Working Pressures (bar)	Date of Incident	Exposure Time	Time of Onset After Decompression	DCS Type
1	Mr S P	Thai	109	CAW	11%	32	1.80	1.2.85	12 hr	A few hours	1
2	Mr S K	Thai	109	Surveying Assistant	6%	28	1.80	1.2.85	10 hr	A few hours	1
3	Mr D C	Thai	109	Forman	20%	39	1.80	8.2.85	12 hr	A few hours	1
4	Mr S T	Thai	109	CAW	9.4%	18	1.95	23.12.85	12 hr	A few hours	1
5	Mr N	Thai	109	CAW	15%	24	1.95	25.12.85	11 hr 45 m	3 hours	1
6	Mr S B	Thai	109	CAW	11.3%	31	1.95	29.12.85	12 hr	1 1/2 hours	1
7	Mr U S	Thai	109	CAW	12%	25	1.95	29.12.85	12 hr	3 hours	1
8	Mr V A	Indian	109	CAW	15%	29	1.75	16.2.86	10 hr 55 m	4 1/2 hours	1
9	Mr KYK	Korean	301	CAW	19%	31	1.90	21.1.87	12 hr 22 m	6 hours	1
10	Mr CJC	Korean	301	CAW	14.2%	35	1.94	16.3.87	12 hr 22 m	28 hours	1

CAW stands for compressed air worker.

FIGURE 1

HUMIDITY AND TEMPERATURE CHART FOR CONTRACTS 109 AND 301

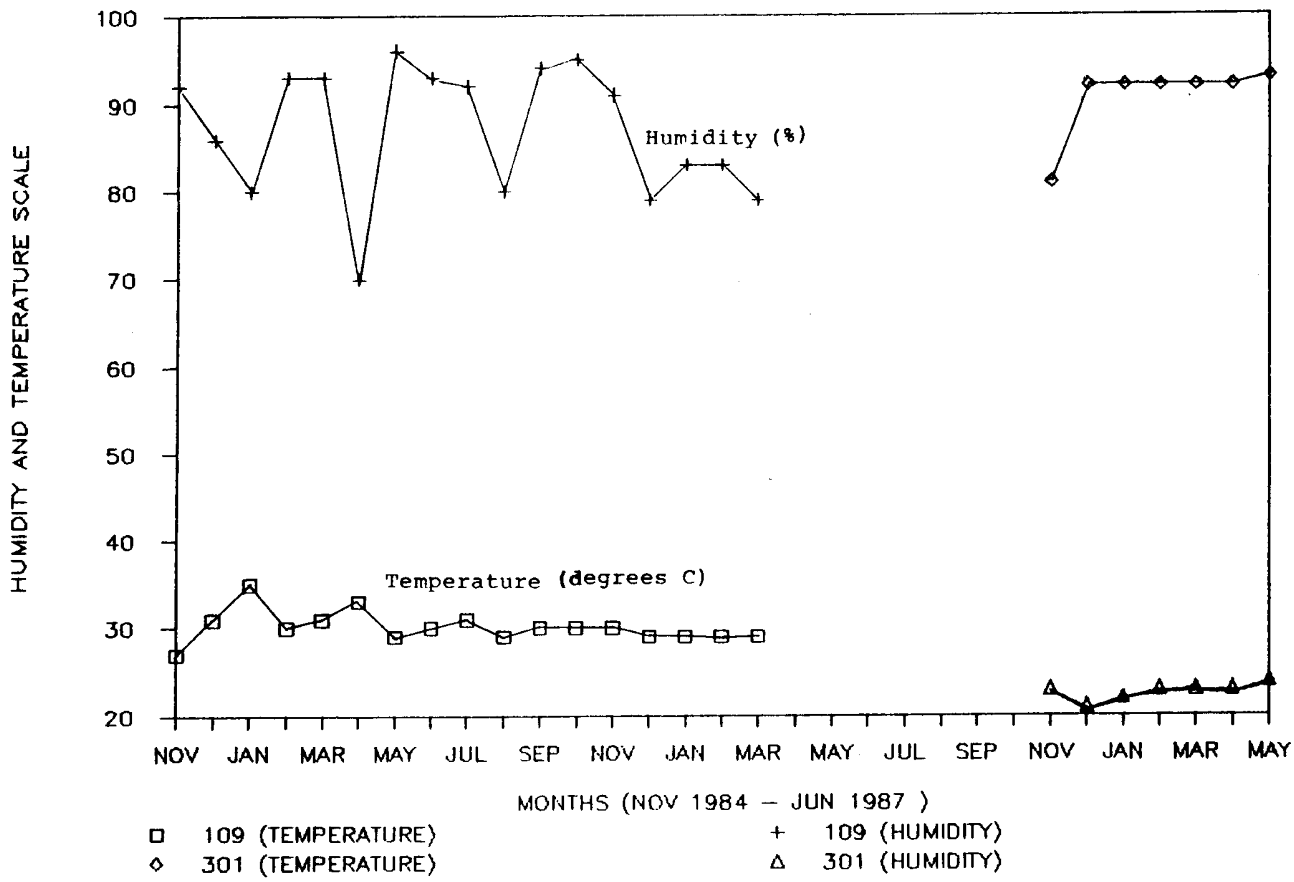

TABLE 3

SUMMARY OF SYMPTOMATOLOGY AND TREATMENT USED

Case	Shoulders Uni	Shoulders Bi	Elbow Uni	Elbow Bi	Hips Uni	Hips Bi	Knees Uni	Knees Bi	Treatment Table Used	Outcome of Treatment
1								*	61	Complete Cure
2						*		*	61	Complete Cure
3	*					*		*	61	Complete Cure
4							*		CIRIA 1	Complete Cure
5		*							61	Complete Cure
6							*		61	Complete Cure
7							*		CIRIA 1	Complete Cure
8				*		*		*	CIRIA 1	Complete Cure
9			*				*		CIRIA 1 and 62	Complete Cure
10				*					CIRIA 1	Complete Cure

Note: Uni = Unilateral Bi = Bilateral

TABLE 2

CLINICAL PRESENTATION

Symptomatology	Number
Pain	
Deep	10
Constant	2
Limitation of movement	3
Joint tenderness	1
Joint numbness	1
Warmth around joints	2

closely opposed surfaces separated by fluid are forced apart. The negative forces or low pressures generated as a result of the separation of the two surfaces result in the formation of bubble nuclei.

Another mechanism where microbubbles may be formed in the compressed air worker is related to the increased haemodynamics in compressed air workers performing heavy work often in temperatures of 40o C. At the molecular level, fast moving fluid particles, by cavitation, generate sufficient negative forces behind the particles to cause the formation of microbubbles. Other mechanisms which may cause microbubble formation include a suggestion by Walder and Evans[2] that spontaneous in-vivo nuclear fission may be the aetiology of gas micronuclei.

Bubble nuclei have been shown to be necessary for bubbles to occur in an elegant series of experiments by Evans and Walder on transparent shrimps.[3] Three groups of 50 shrimps were decompressed from seal level to 0.079 ATA. One group was pressurised to 389 ATA before being decompressed. A second group was not pressure treated. In the pressure treated group 4 shrimps were seen to contain bubbles while 48 did so in the non-pressurised group. The third group was pressurised and then electrically stimulated. 16 of these shrimps developed bubbles on decompression. It has been argued that the bubbles originated from gas nuclei, and that the first batch of shrimps had their in vivo bubble nuclei squashed out of existence before being decompressed. This reduced the capacity of supersaturated tissues to form bubbles.

The compressed air worker enters and exits from compressed air daily after spending long hours in the compressed air environment. This form of repetitive exposures greatly increases their chances of DCS. Experience from repetitive dives in fisherman divers have shown that there is an increase in incidence of DCS in the second and subsequent dives. In the first exposure, small asymptomatic bubbles may have been formed. In the subsequent exposures, these asymptomatic small bubbles formed sites of further bubble growth, accounting for the increased incidence of DCS in subsequent dives.

Bubble micronuclei do not cause symptoms by themselves. The compressed air worker must have enough gas loading in his tissues to enable the bubbles to grow. In addition, the rate of decompression must be great enough to overwhelm the compressed air worker's circulatory capacity to transport the excess nitrogen from the tissues to the lungs.

Although the compressed air workers were decompressed according to the CIRIA recommendations[4], they had spent more than 8 hours in the compressed air tunnels. It is possible that there are very slow tissues that become totally saturated only after long exposure times. During decompression, nitrogen is released, but because of the slow half-times, the rate of nitrogen elimination could have resulted in bubble formation localised in these slow tissues. Tissue bubbles, when formed, can cause physical distortion of the tissue planes and stretch nerve endings. This is manifested as the symptoms of pain and numbness.

Slow decompression to eliminate the problem of DCS in compressed air workers has been advocated since the the 19th century. Haldane[5] believed that bubbles were not formed if the drop in ambient pressure did not exceed a ratio of 2:1. The variable time course of nitrogen uptake and subsequent elimination could be simulated by a family of discrete hypothetical half-time tissues. Haldane took tissues with half-times up to 75 minutes to develop his decompression tables which were adopted by the British Admiralty. Subsequent development and improvements to Haldane's tables were later adopted for various compressed air tunneling projects in England. In 1958, Hempleman devised the current compressed air tunnel tables (Blackpool Tables) which were incorporated into the CIRIA report.[4]

The disadvantage of using the CIRIA procedures for decompression of our compressed air workers from less than 1 bar exposure was the fact that very long half-time tissues were not considered. Our workers worked for between 8 to 12 hours at pressures approaching 1 bar gauge with 12 hours on the surface. Benhke[1] had proposed that there are tissues with up to 120 min half-times which will require up to 14 hours to desaturate 99%. Calculations for the decompression times for divers with exceedingly long exposures must take this into consideration. The interval between exposures must also be greater than the 14 hours for these long half-time tissues. The compressed air workers therefore may have accumulated nitrogen due to the long exposures and repetitive nature of their work. This is a possible reason why some of our compressed air workers developed DCS as they had worked longer than 10 hours within the tunnels and had spent less than 12 hours at the surface.

The US Navy's experience with long and deep exposures have also revealed deficiencies in assuming Haldane's

2:1 ratio for decompression. They found unacceptably high rates of DCS when assuming Haldane's theory of using a 2:1 decompression rate. A better proposal was made by Workman.[6] He suggested that blood perfusion of the tissues (excluding tissue diffusion) is the chief factor affecting the rate of gas transport. In his calculations, Workman considered more tissues as well as slower tissues, some with half-times of 1,000 minutes. The critical ratio varied at each depth for a particular tissue. He devised a linear scale of "M" values, showing the maximal allowable supersaturation for each hypothetical tissue at each depth for the whole range of decompression for nitrogen and helium diving. These formed the basis for the derivation of the US Navy Tables.

The decompression tables of the US Navy and the tables promulgated in the CIRIA report may have, in general, prevented symptomatic bubbles from occurring in the compressed air workers. Brian Hills[7] proposed a thermodynamic model of DCS from his work with pearl divers working out of Broome, western Australia. He introduced the tern tissue un saturation based on the lower total partial pressures of gases in the tissues and venour blood when compared with the alveolar air and arterial blood. He suggested that although bubbles develop on decompression it requires a 6o mm Hg drop in pressure before the tissues become saturated with gas. He suggested that gas bubbles are formed during decompression with the US Navy tables and the decompression rate merely controlled the size of the bubbles. The primary event and the critical insult which produced the symptoms of DCS do not coincide. The primary event is the activation of one or more of a reservoir of nuclei normally present in tissue into growth and hence the inception of a stable gaseous phase. The inception of this gas phase occurs randomly.

It is possible that limb pains are caused by the local pressure of a bubble distorting a nerve ending beyond its pain provoking threshold. The onset of limb DCS is dependent upon the volume of gas separated from solution. The inception of bubbles in the limbs of compressed air workers can be profuse and rapid due to the presence of micronuclei created by tribonucleation and cavitation in the joint. As a result the tissue can only withstand minimal supersaturation before gas in excess of thermodynamic equilibrium forms bubbles.

The compressed air workers worked at high temperature and humidity for long durations. An additional contributing factor to be considered is dehydration. Dehydration reduces the circulating blood volume. During decompression, the increased gas load at the tissue levels may not be eliminated fast enough due to the reduced blood volume. This may cause a build up of bubbles in the tissues resulting in symptoms of DCS.

Alcohol is known to cause tachycardia and vasodilatation, which may cause haemodynamic changes in the body. Although alcohol ingestion was denied by all the workers, there is no assurance that alcohol was not imbibed before they entered the tunnel.

Age and obesity have been noted in factors that predispose workers in the development of DCS. Older workers tend to have less efficient cardiovascular systems which possibly result in a reduced capability to clear the excess nitrogen. In Singapore the manual labourers were less than 35 years old. The obese workers, who had greater than 24% body fat, were given limited duration exposures to compressed air work. The 10 cases of DCS were neither old nor obese and are therefore unlikely to be affected by these factors.

One of the patients gave a history of working from 8 a.m. till about 8 p.m. in the tunnel. Then from 4 a.m. to 7 a.m. he moonlighted as a newspaper distributor to supplement his income. This may have precipitated the development of DCS as prolonged exertion results in an increase in the number of bubble nuclei, and the sites where further bubble growth could occur.

Our experience was that 90% of the cases of DCS at less than 2ATA occurred when the pressure was greater than 0.8 bar gauge. Two cases, one at 0.94 bar gauge (Case 9) and one at 0.9 bar gauge (Case 10) exceeded the 12 hour limit of the CIRIA recommendations. A disadvantage of using the CIRIA regulations in that for exposures less than 1 bar, regardless of the exposure time, no decompression stops are required and the compressed air worker can be decompressed direct to the surface. The assumption that DCS does not occur if the exposure pressure is less than 1 bar must be questioned in the light of our experience.

The 10 cases of DCS occurred in young and healthy individuals of a mixed ethnic group. There were no obvious individual predilection to DCS. Various factors related to the nature of the work like heavy manual labour and repeated entries into the compressed air environment may have resulted in the formation of microbubbles through the process of tribonucleation and cavitation. The long exposure times and the rate of decompression caused the microbubbles to grow and produce symptoms in these 10 compressed air workers. Exactly why it happened in these 10 compressed air workers and not the other compressed air workers, we cannot be certain. Perhaps there is an individual predilection or an individual daily variation of susceptibility.

This conclusion seems to be in line with the conclusion drawn by Benhke[1] of the 9 cases of DCS that were seen following exposures between 11.5 and 16 p.s.i. gauge in the BART project in the USA.

DCS and diving to shallow depths

The mechanism in which DCS can occur at shallow depths is similar to that seen with the compressed air workers. The likelihood increases when repetitive dives are done or when divers use surface supply equipment to prolong their stay underwater to allow them to dive for hours.

Even with breath-hold diving, DCS can occur if the duration and depth is long enough. This condition, called Taravana, was an observation reported by various authors amongst the Pearl divers of the Tuamotu Archipelago. Repetitive breath-hold dives up to 40-50 times a day are performed. The islanders hyperventilate for periods ranging from 2 to 10 minutes. During descent, the diver holds a lead weight between his feet and the rope in one hand. With the free hand the diver grasped his nose to assist in equalisation of his ears and sinuses. The divers dive to depths of 120 feet for 1 to 2 minutes. Cases of severe vertigo, nausea, paralysis, unconsciousness, mental derangement and deaths were reported among these divers.[13]

Medical Problems in Diving

The sea is strange and mysterious environment. Throughout the ages, legends about large sea monsters, about falling off the edge of the earth, the names Roaring Forties and Furious Fifties, all portray Man's fear and uncertainty about our oceans. The psychological aspects of sports diving must not be ignored by diving physicians as fear, ignorance and insecurity can contribute to or complicate a diving accident. Experienced divers can think through problems and go through the drills that have been taught to them, such as ditching the weight belt, controlled ascents, buddy breathing, but an inexperienced, anxious or fearful diver will most certainly find difficulty in doing the same tasks.

Proper medical selection therefore should take into account of the psychological maturity and confidence of the diving candidate. A weaker swimmer is less likely to be able to remain afloat for as long as a strong swimmer. A candidate psychologically fearful that his equipment will fail on him can run the risk of panic and rapid ascent, with drastic consequences. Similarly, one who is fearful of the dark or the deep, or has an intense fear of sharks, can endanger his own life, and even his buddy's, should he panic and do something silly.

Certain medical conditions should exclude a person from diving. These include asthma, epilepsy or a previous seizure episode, ischaemic heart disease, and cardiac arrhythmias which may lead to a sudden ventricular fibrillation (e.g. Wolf Parkinson White Syndrome).

Diving in unfamiliar situations

Inexperience plays a large part in many of the cases of diving accidents occurring in shallow waters. It may occur with newly qualified divers or with divers who have laid off for some time. Certain areas in diving are more risky, and divers require preparation and training prior to attempting the dive. Worthy of special mention is diving at night, in sink holes, caves, fresh water, springs and wrecks. Divers, experienced only in one area of diving, must be considered novices when doing another category of diving, as techniques and safety procedures are different.

Not every diver will dive regularly throughout the year. Frequently, the newly qualified divers take a diving course only to lay off diving for a considerable time. In temperate countries, the onset of the winter season usually heralds the end of the diving for the year. Approximately 4 to 6 months later, when the weather finally gets warm enough for diving, the diving season begins again.

Hazards of diving to shallow depths

In considering the hazards of diving at shallow depths, the following categories may be used.

(a) Environmental hazards
(b) Hazards due to equipment
(c) Hazards caused by individual factors

ENVIRONMENTAL HAZARDS

The problems of diving in unfamiliar situations are manifold. Even for the experienced diver, preparation and planning must be detailed. Planning should include a complete appraisal of the dive area, the equipment used and a self appraisal of one's capabilities.

The environmental conditions to be noted at the dive site include:

(a) Depth of the water
(b) Sea state, tidal conditions and strength of the current
(c) Water visibility
(d) Temperature of the water
(e) Time of the dive
(f) Types of marine life which will be encountered
(g) Obstacles expected to be encountered.

The dangers of breath-hold diving at shallow depths include hyperventilation hypoxia and hypocapnia. Hyperventilation hypoxia results when the diver hyperventilates before diving producing hypocapnia. During the dive there is progressive hypoxia, but because of the low levels of CO_2, respiration is not stimulated before unconsciousness overcomes the diver. The cause of death, if not rescued, is aspiration and drowning.

Careful consideration of the environmental conditions is important. Diving in poor sea conditions or strong currents is dangerous and should always be avoided. Breaking surf, currents greater than 1 knot, stormy weather, bad sea states and impending darkness all pose potential problems for divers and the crew of their dive boats. Aside from seasickness in the persons on board the dive boat, the diver attempting to return to the boat on the surface may lose sight of his dive boat in heavy seas. An experienced diver is usually able to sustain a swim at about 1 knot for only a few minutes. Diving in currents in excess of 1 knot is foolhardy and can result in divers being swept away.

Diving at night and in poor visibility requires planning and coordination between the diver and his buddy as well as with the dive boat. Divers should practice safety drills and equip themselves with the appropriate buddy lines, torches, and if possible flares, in order that the dive boat can locate divers who have gone adrift.

Underwater entrapment is a common cause of diving accidents and this can occur in the experienced diver. Seaweed (especially kelp), coral formations, rock outcrops, caves, wrecks, ropes and fishing nets all pose potential hazards for the diver.

Cave diving, diving in sink-holes, springs and quarries requires good planning and adequate equipment. Lifelines, torches, reserve tanks and other safety equipment must be taken and used to ensure safety.

Adequate maintenance of body heat is necessary and the early symptoms of hypothermia, like shivering, should be heeded and preventive actions taken. If hypothermia is prolonged, it will lead to a progressive deterioration of mental function, and unconsciousness. The patient eventually develops ventricular fibrillation and dies. Adequate thermal protection, like wetsuits or dry suits, to prevent heat loss should be used in cold water.

Although shark attacks constitute less than 1% of all diving fatalities, prudence in selection of a dive site is required, especially if shark attacks or sightings have been reported lately.

EQUIPMENT FACTORS

A diver should become familiar with the equipment to be used. This is especially so for rented equipment. Particular attention should be focussed on the mechanism for the release of the weight belt and the inflation of the buoyancy compensator. Pre-dive checks should include recognition of the location of the buckle for the weight belt and to ensure that the weight belt buckle does not rotate out of reach while in the water.

An important piece of equipment is the buoyancy compensator (BC). This must be stored properly when not in use to prevent premature deterioration of the rubber and plastic components. Pre-dive checks should include a test for leaks in the BC to ensure that it functions properly. Checking the BC prior to the dive should also involve the inflating mechanism. Most BCs now are inflated from the diver's air tanks using a power inflator. This set up is elegant but divers should be aware that at the end of the dive, when the air has run out, the BC cannot be inflated. This can lead to a minor crisis especially if the diver is overloaded with a haul of treasure or abalone. Quick thinking and action is required to avert a tragedy. Other BCs are equipped with a CO_2 cartridge which inflates when a ripcord is pulled to activate a triggering mechanism. Corrosion, due to poor maintenance, can jam the triggering mechanism, preventing its activation. Alternatively, the CO_2 cartridge may have already been used or has leaked. Checking the cartridge is therefore important.

Steel air tanks should be properly maintained. The air used for charging steel cylinders must be free from moisture. Corrosion can occur on the inside of the tanks and deplete the oxygen within the tank. There is a danger of hypoxia if a steel tank that has been stored full for a long time is used. In any case a corroded steel or aluminium tank is dangerous and may crack or explode when charged. Owners of scuba tanks should be aware of this danger and ensure regular hydrostatic testing by an approved authority.

Two other important but often ignored pieces of equipment are the depth gauge and the contents gauge. Depth gauges should be calibrated regularly as, in our experience, they are often inaccurate by up to 15%. This can result in a miscalculation of the diving profile and increases the risk of decompression sickness. Contents gauges should also be maintained properly to ensure correct readings. Divers should regularly consult their contents gauges to check on the amount of air left.

Diving in polluted and heavily silted waters can result in failure of the second stage regulator. Fatalities have been reported when diving in quarries which were heavily silted.

For the sake of completeness, I would like to mention a few dangers faced by military divers at shallow depths. These problems usually arise with the use of specialised re-breathing apparatus. The problems include oxygen toxicity, carbon dioxide retention, hypercapnia and caustic soda burns.

Oxygen toxicity in the military diver occurs usually when the diver exceeds the prescribed depths. The divers have to perform strenuous tasks underwater and this increases the rate of development of oxygen toxicity. There is considerable individual variation in the tolerance to oxygen toxicity. In Singapore all military divers have to undergo an oxygen tolerance test to exclude those divers in whom there is a high susceptibility to oxygen toxicity.

Carbon dioxide retention occurs when the CO2 absorbent material (usually soda lime) has either been packed too loosely or when the potency of the chemical has diminished. Caustic burns occur when salt water comes into contact with the soda lime in the re-breathing set. This may occur with poor technique, with water leaking from the mouthpiece, or when leaks occur in the system. Salt water combines with the soda lime to give off caustic soda (sodium hydroxide). This can be aspirated, causing burns to the lips and throat, as well as a nasty surprise for the diver. However, there is a danger of the diver panicking and rushing to the surface.

PERSONAL FACTORS

Individual factors can predispose to hazards and accidents in diving. It is usual for the beginning of the season to see accidents happen to divers who have not been diving during the off season. Divers must be aware of their limitations and capabilities. Meticulous planning is important in ensuring safe and enjoyable dives. Detailed planning of the dive should include the calculation of the amount of air required for the whole duration of the dive including allowances for delays and decompression stops. In shallow diving, planning before a dive is still required. Decompression sickness may occur, with very long exposures and especially with surface supply equipment.

Pulmonary barotrauma, with drastic consequences, is still likely when divers run out of air and they fail to notice it until it is too late. Frequently, divers in panic situations (e.g. running out of air or aspiration of small quantities of water) hold their breath and rush to the surface. This may result in fatal air embolism as the expansion effects of the bubbles is greatest between 1 bar and the surface.

Alcohol ingestion has been shown to be one of the main contributing causes to drowning. Drinking and diving can result in carelessness and poor judgement among divers. This can contribute to fatalities. In addition alcohol ingestion has been related to an increase in the risk of decompression sickness.

Untrained divers should not attempt to dive unless undergoing a proper dive course. In Singapore, there is no legislation preventing untrained persons from buying diving equipment. Proper medical clearance and diving training is essential in ensuring safe diving. Safety drills, buddy breathing, rescue and cardio-pulmonary resuscitation are important skills to be learnt by the budding diver.

Poor technique and improper training can lead to problems of equalisation of the ears. Conditions like sinus and aural barotrauma may complicate the dive. Frequent comments such as "Boy! My eardrums are bursting. Those divers must have eardrums made of steel", demonstrates the ignorance of the general public about the proper techniques in diving.

Vertigo due to unequal vestibular stimulation or tympanic membrane perforation can result in disorientation and panic in inexperienced divers. Of even greater concern is the danger of pulmonary barotrauma and air embolism in untrained divers who are asthmatics or who breath-hold during ascent.

Drugs can have side effects which may reduce the reflexes and motor coordination of divers. Taking antihistamines may reduce the nasal congestion of divers with colds, but at the same time, it may cause drowsiness in some divers. This is potentially risky and can cause accidents due to misjudgment. Addictive drug abusers should be condemned and disallowed from diving as they cause dependence, impaired consciousness and disorientation.

Heavy smokers run risks of chronic bronchitis and obstructive lung diseases after continuing with their habit for many years. These lung conditions can lead to air trapping and potentially hazardous pulmonary barotrauma. Smokers who intend to continue diving should stop smoking. It is also a good idea for all divers to have a proper medical every year which include a full sized chest X-ray and spirometry.

Wherever possible, the inexperienced diver should be accompanied by an experienced buddy when an unfamiliar form of diving is carried out. The buddy system allows the experienced diver to keep the inexperienced diver out of danger. Many reports of diving fatalities cite inexperience as one of the main contributing factors to fatalities. For instance:

A newly qualified diver was killed recently when strong currents swept him away from the dive boat. He was found later, with a fractured skull and bruises on his head, face and body.

Another incident occurred where a woman diver got into difficulties at depth and although she was diving with her boyfriend, only the boyfriend managed to ascend to the surface. Her body was never found.

Conclusion

Prudent planning and a level headed approach to diving preparation is essential for a successful and enjoyable diving expedition. There are dangers even in shallow water diving but these can be safely overcome.

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Editorial, continued from page 77.

awareness of both the advances in our knowledge of diving related problems and of how much still remains uncertain. This is shown by the numerous versions of diving tables and the occurrence of cases described as atypical decompression sickness. After a short period of total ignorance there grew a belief that all problems related to diving had been identified and were fully understood. There is now a growing awareness of the complexity of the changes which can follow an alteration of the ambient pressure ant that these are influenced by seemingly innumerable factors. Complacency is the one deadly sin we cannot afford to condone.

Although Adlai Stevenson once made the somewhat debatable comment that the function of an editor was to separate the wheat from the chaff and print the latter, it is believed that no such assessment should be made of the many and varied papers that have appeared in the SPUMS Journal over the years. It is hoped that readers have been informed, interested and sometimes provoked into considering that some hitherto unquestioned belief should be re-examined. If that is so the Editor has been successful. From the next issue Dr John Knight takes over as Editor. His years of experience in the production of the Journal as Assistant Editor and as Deputy Editor make him an excellent choice and I am sure that the Journal will continue to prosper.

SPUMS ANNUAL SCIENTIFIC MEETING 1990

SCIENTIFIC PAPERS

Saturday, 2nd June, 1990

Ruth Inall
SPUMS and the Science Centre Foundation

Warwick McDonald
The DITAA analysis of the recreational diving industry

Martin Sher
The future of recreational diving

Sunday, 3rd June, 1990

Chris Acott
Diving incident monitoring

Courtenay Kenny
Dysbaric illness treated at HMNZS PHILOMEL

Peter Chapman-Smith
Case studies

Greg Adkisson
Diving accidents in the United Kingdom

Monday, 4th June, 1990

Greg Adkisson
The 1988 BSAC decompression tables

Drew Richardson
PADI decompression teaching in 1990 ()

Raymond Rogers
The development of the DSAT (PADI) decompression tables

Raymond Rogers
Testing of the DSAT (PADI) decompression tables

Tuesday, 5th June, 1990

Greg Adkisson
SPECT studies and cerebral decompression sickness

Des Gorman
Pathophysiology of cerebral arterial gas embolism

Chris Acott
Psychiatric disorders in diving

Warwick McDonald
Women in diving

Wednesday, 6th June, 1990

Greg Adkisson
Submarine rescue

Lori Barr
Case reports of tank carrier's lateral condylitis

Lori Barr
A biomechanical model of tank carrier's lateral condylitis

John Robinson
Vertigo in diving

ANNUAL GENERAL MEETING.

Thursday, 7th June, 1990