South pacific underwater medicine society

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C O N T E N T S

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EDITORIAL

It is a sad but true reflection of human nature that there would be little or no medical interest in diving were it not for the discovery that there were complex problems affecting divers that were not to be met with in the conventional fields of medicine. Were it not for the modest but still continuing toll that these problems exact, shown only fleetingly by the inadequate statistics, the diver population would have continued to exclude the intrusion of such curious people. It is becoming clearer with time that our understanding of our own physiology is slighter than had been believed and in this field of knowledge in particular the simile of the Iceberg rather than that of the Bikini is appropriate. The papers in this issue seek to add a little more to our appreciation of the presently recognised problems. Isaac Asimov has written that "Man's greatest asset is the unsettled mind and our hopes of reasonable safety as we progress longer and deeper underwater depend in large degree on our continuing to ask - What, How and Why of every significant deviation from the expected. We are unlikely ever to run out of fresh problems to spur us on."

There appears to have arisen in recent years an undue delicacy among the Naval Services regarding the publication of case notes and reviews of their actual experience with patients. There has been a retreat into the presentation of statistics of diagnoses, the validity of which must be taken on trust. The charitable will accept that the various authors never found difficulty in reaching certainty. It is for such, and other, reasons that the review of the experience of the Naval Diving School of South Africa is especially welcome. Dr AG Jones' remarks on the deficiencies in old records will bring sighs of understanding from readers everywhere, and his suggested Proforma is a stage beyond the brief check list given at one time to Royal Naval medical officers entering chambers. The effect of high partial pressures of "inert" gases on medical efficiency is a matter that is under consideration in the UK, where the problems of surgery on injured divers under deep saturation conditions are a nightmare not yet openly faced. The case notes on the Air Embolism cases are welcome, as also the brief mention of non-recompression responsive conditions treated in "error", though possibly correctly so treated under the circumstances. It is deeply regretted that there are no more details of the Curry Case! Those to whom a Chamber seems the answer to everything should notice that the chamber itself can cause trouble.

Not all mammals are as Johnny come lately to diving as is man, a fact that Mr TT Davies considers for our edification. The comparison of the dive bradycardia of the Grey Seal (from 130 bpm to 4 bpm in one minute) with that of man (a mere 50% reduction), the former going deeper for longer and swimming more actively, shows something of the versatility of mammalian physiology. We are indeed a long way separated from the marine iguanas who graze with complete unconcern 10 metres deep, totally unaware of the multitude of problems that should make this behaviour impossible. One cannot imagine this author regarding a whale merely as a convenient source of engine lubricant!

If you want problems that are problems, dive off the North Sea Oil Rigs. Commander Warner's paper indicates some of the more severe misadventures that have occurred there being limited to fatalities. That a person of his determination to investigate should be able to obtain so little real information concerning some of the fatalities is an indication of the low level of awareness and concern amongst those involved regarding the value of investigating morbidity and mortality as a first stage in the fight to reduce it. Anyone who believes that the Diving Industry is fully aware of the need to anticipate and circumvent trouble could do well to read the article by Margaret Hamilton (New Scientist, 2 Dec 1976). It is apparent that man's ability to do remains far in advance of his willingness to face the consequences of his doing. Deep Saturation Diving in potentially dangerous conditions is a prime example of this.

Our next issue will bring Commander Warner's story through 1976. In the meantime, Commander Warner's other paper solicits your interest and opinions regarding deep offshore diving problems. '

Accidents will continue to occur and Dr Victor Brand presents a case for discussion. This illustrates the build up of factors that so often set the scene for the incident itself to dramatically change the course of the dive The non-fatal outcome is exceedingly welcome to the author's many friends. Professor Nemiroff has produced further material for discussion and serious consideration. There has been word from another correspondent stating that predicted would occur by Professor Nemiroff in the last issue. It is hoped that no other cases will occur. The case itself may be written up at a later date.

Dr Gavin Dawson reports on the use of one-man chambers for OHP therapy. There appears to be a legitimate place for such chambers, subject always to their being operated by thoroughly trained personnel. It is claimed that no such chambers have ever caught fire, but only extreme care will maintain this safety record. The indications for such therapy are still debatable, chronic conditions now often being thought inappropriate for treatment while acute Head and Spinal injuries are being offered the OHP on a test of therapy basis. Some believe that the air breaks and "depths" have been set too conservatively in the past. This subject is an area of debate and change and further papers are likely to be written by those involved.

The final common pathology of the majority of fatal diving incidents is drowning. The unlucky divers pinned down by Dr Doug Walker's "Stickybeak" seem to have been either dead or brain damaged, and therefore beyond successful resuscitation, when reached. The short time interval required to reach this condition should be a stimulus to practicing diving on an avoid-danger rather than a treat-trouble philosophy. The value of a good buddy and a working buoyancy aid should by now require no further endorsement. It is reassuring to hear from Dr John Pearn that successful resuscitation leaves children at least with no apparent residual ill effects in the vast majority of cases. That the survivors have an IQ average of 110 is not to suggest that no damage has occurred, for pre-incident data regarding IQs is unavailable. The finding that 10% of the children were resuscitated by other children is amazing and should stimulate a drive to ensure that ALL divers are capable of undertaking such measures. That the first signs of response are often followed by vomiting is another finding of value, as the awareness of this problem makes the correct immediate reaction more likely. The use of OHP therapy for "drowning" cases has been advocated by Dr Eric Kindwall. It has been shown to reduce the intracranial pressure by a factor of 40-50% within minutes of reaching pressure. This is apparently not a direct pressure effect and may be due to a vasoconstrictor effect on the brain. Despite such vaso-constriction of larger vessels brain tissue O_2 is increased under the hyperbaric conditions. As cerebral oedema produces increased anoxia there could be place for this use of one man chambers on occasion.

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All contributors are thanked, as also BAROLOGIA (South Africa). It was for a meeting of this Society that the papers by Dr Jones and Mr Davies were first researched and delivered. And if you disagree with some of the comments here presented, perhaps they were intended to start discussion. This is YOUR Society so send in your contributions.

ANALYSIS OF DECOMPRESSION SICKNESS CASE TREATED AT THE SA NAVY DIVING SCHOOL, 1962-1976

Surgeon Commander AG Jones - Diving Medical Officer, South African Navy

The SA Naval Diving School was established on the 1st of July 1957. A 10 man decompression chamber was installed and it became operational in 1958. From this date towards the end of 1960 it has been used solely for training and testing of equipment.

The first therapeutic decompression was done on the 5th January 1962. While this was still in progress a second diver with the "bends" was brought in. He had to be compressed in the one man compression chamber for the interim period, and was later transferred to the main chamber for his therapeutic decompression. Since this flying start a total of 70 therapeutic decompressions has been done up to the present.

INDICATIONS FOR THERAPEUTIC DECOMPRESSION

Any diver suffering from decompression sickness, pulmonary barotrauma with air embolism or any obscure symptoms of sickness which cannot be clearly attributed to other causes must undergo therapeutic decompression. Recompression does not cause any damage and can prevent serious consequences.

DECOMPRESSION SICKNESS

When a person is subjected to an increased pressure, the raised partial pressure of the nitrogen will cause an influx of nitrogen, via the lungs, into the body tissues. With a decrease in pressure the reverse will happen and nitrogen will flow from the tissues to the lungs until an equilibrium is reached.

When this pressure decrease is above a critical level, the escaping nitrogen can not be passed to the lungs fast enough for elimination and micro-bubbles of nitrogen may form. They may coalesce to form bubbles which may cause obstruction in the smaller blood vessels. The symptoms caused by these bubbles is known as decompression sickness.

TYPE I DECOMPRESSION SICKNESS

This includes all the cases where pain is the only symptom. It is normally situated in or around a joint. Skin and lymphatic manifestations are also included in this group.

TYPE II DECOMPRESSION SICKNESS

This includes all the more serious symptoms such as neurological, vestibular and respiratory symptoms.

PULMONARY BAROTRAUMA

Due to overexpansion of the lungs, ruptures may occur. Air may be forced through these small openings into the circulation and again cause obstructions of the vessels. This is a very sinister problem and requires immediate recompression.

BREAKDOWN OF CASES INTO TYPE OF ACCIDENT

Type I	44
Type II	12
Pulmonary barotrauma with air embolism	11
Incomplete records	3
Total	**70**

EVENTS LEADING UP TO ACCIDENT

		TYPE I	TYPE II	AIR EMBOLISM
1.	No decompression schedule	26	7	
2.	Simulated dives in a compression chamber	4	3	1
3.	Caisson Workers	6	1	
4.	Equipment failure followed by free ascent			5
5.	Inaccurate depth or bends on an apparently safe table	6		
6.	Breathhold or controlled breathing			4
7.	Flying after diving	1	1	
8.	Attendant during therapeutic decompression	1		
9.	Nitrogen narcosis			1

BREAKDOWN OF SYMPTOMS AND SIGNS IN AIR EMBOLISM

A. Presenting Symptoms

1.	Pain in chest	4	approx 37%
2.	Unconscious	2	± 18%
3.	Apnoea	1	± 9%
4.	Blindness	1	± 9%
5.	Headache	1	± 9%
6.	Pain in elbow	1	± 9%
7.	Pain in lumbar area	1	± 9%

B. Most common signs and symptoms in air embolism

1.	Pain:			
	Chest	7		
	Lumbar area	2		
	Elbow	1		
	Thigh	1	11	± 33%
2.	Paralysis + paresis:			
	Arm	1		
	Right sides hemiparesis	1		
	Lower extremities	2		
	Facial hemiparesis	1	5	± 14%
3.	Disorientation		3	± 9%
4.	Headache		3	± 9%
5.	Apnoea		2	± 6%
6.	Convulsions		2	± 6%
7.	Dizzy (vistibular)		2	± 6%
8.	Sensory fallout lower extremities		2	± 6%
9.	Urine retention		2	± 6%
10.	Coughing up blood		1	± 2%
11.	Blind		1	± 2%
12.	Foam in mouth		1	± 2%

TYPE I DECOMPRESSION SICKNESS

Most Common Sites of Pain

1.	Shoulder	17	± 34%
2.	Knee	13	± 30%
3.	Elbow	5	± 12%
4.	Hip	4	± 10%
5.	Ankle	3	± 7%
6.	Wrist	2	± 5%
	Upper extremities	24	54.5%
	Lower extremities	20	45.5%

TYPE II DECOMPRESSION SICKNESS

A. Most Common Serious Symptoms and Signs

1.	Dizzy	6	± 33%
2.	Lumbar backache	5	± 31%
3.	Headache	2	± 11%
4.	Clonus of ankle	1	± 5%
5.	Pain in chest	1	± 5%
6.	Paresis from waist down	1	± 5%
7.	Paresis R leg	1	± 5%
8.	Sensory fallout R leg	1	± 5%

B. Most Common Sites of Pain

1.	Knee	5
2.	Ankle	2
3.	Shoulder	2
4.	Hip	1
5.	Paralysis both lower legs	1
	Upper extremities	2
	Lower extremities	8

THERAPEUTIC DECOMPRESSION TABLES USED

The type of therapeutic decompression table used will depend on three major factors:

1. the type of diving accident;
2. the response of the diver to the therapeutic decompression; and
3. the availability of oxygen in the decompression chamber.

THERAPEUTIC TABLES USED

1.	Long Air table 50 metres for 38 hours 55 minutes	17 }	
2.	Air table 50 metres for 19 hours 43 minutes	15 }	
3.	Air table 50 metres for 9 hours 43 minutes	12 }	
4.	Air table 30 metres for 6 hours 52 minutes	11 }	79%
5	Oxygen table 18 metres for 2 hours 15 minutes	7)	
6.	Oxygen table 18 metres for 4 hours 45 minutes	8)	21%
	TOTAL	70	

Relapses after therapeutic decompression where recompression was needed:

1. One caisson worker after treatment on air table for 9 hours 43 minutes.
2. After treatment in Durban - table unknown.
3. Crayfish diver on air table for 9 hours 43 minutes
4. Air embolism case on O_2 for 4 hours 45 minutes.
5. One death in the chamber due to air embolism on air table 19 hours 43 minutes.

NON-DECOMPRESSION SICKNESS CASE TREATMENT IN CHAMBER

1.	Reverse barotrauma due to curry	2
2.	Hyperventilation	1
3.	Influenza	1
4.	Reverse barotrauma sinuses	1
5.	Inner ear infection	1

DISCUSSION

General

The information was obtained from the medical and SA Naval Diving School records. Symptoms and signs as reported have been analysed to compile this paper.

Incomplete and vague recording that was encountered, could be ascribed to the following:

1. Therapeutic recompression to a depth of 50 metres has been used in 63% of the cases. At this depth nitrogen narcosis will affect the examining medical off icer to such an extent that a thorough examination becomes very unlikely.

2. No laid down proforma of the medical examination of decompression accidents has been used to ensure a complete examination. This would also be of immense value for future research into these cases. See Appendix A.

PULMONARY BAROTRAUMA WITH AIR EMBOLISM

The very high incidence of pulmonary barotrauma with air embolism (PBT) in this series (16%) stresses the importance of preventing this sinister condition. It is always preventable. The most important single factor was panic in inexperienced divers.

DECOMPRESSION SICKNESS

The most common single factor here was total disregard of laid down decompression tables. This was very much so in the days of the crayfish diver and before the Regulations on diving has been instituted through the Factories, Machinery and Building Work Act, through the Department of Labour.

it is interesting to note that the occurrence of pain in the upper extremities has been more frequent than in the lower extremities.

This confirms the findings of other workers in this field. Also the higher incidence of pain in the lower extremities in airlock workers follows other findings.

APPENDIX
BLAST THAT FISH

Alf Leggatt, who was awarded the NBE for his services to fishing, asked the army to blow a perch out of his pond because it had eaten 2000 goldfish there. The army obliged and exploded two charges. But the perch stayed put. Nicknamed “Jaws” to commemorate his appetite, he remained an unwelcome victor. His reign only closed when the Southern Electricity Board sent two men to shock him. They used an electrified fishnet, 20 minutes and 240 volts to complete the assignment. As Alf said when his enemy floated stunned to the surface, “I knew I’d get him in the end - I wouldn’t let a thing like this beat me. But I must admit I’ve developed a grudging respect for him”. So he put Jaws, all of 31 cms long, into a separate pond in front of his house. Jaws quickly recovered and swam strongly round the pond.

“He looks hungry,” said Alf.

UK News reprint

DECOMPRESSION ACCIDENT REPORT FORM

Date: .... Unit: ....

1. No .... Rank: .... Name: ....

2. PRINCIPAL SYMPTOM or MAIN INJURY

3. Type of dive .... 4. Depth: ....

5. Time of accident: .... 6. Time of surfacing: ....

7. Bottom time: .... 8. Ascent time: ....

9. Type of diving equipment ....

10. Decompression shortened.... 11. By how much? ....

12. Explosive ascent? .... 13. Therapeutic table in use: ....

14. Combined dive? .... 15. Diver Qualification: ....

16. FIRST SIGNS:

	COMMENTS	YES	NO
17. PAIN - Localization			
18. SKIN OR CUTANEOUS Manifestations			
19. CANIAL NERVES			
- Deafness			
Vertigo, Nausea, Vomiting			
- Visual problems			
- Pupil size			
- Rhomberg's sign			
20. INTRACRANIAL			
- Headache			
- Level of consciousness			
- Fully conscious			
- Confused but rousable			
- Responding only to pain			
- Deeply unconscious			
- Fatigue			
- Personality disorders			
21. PERIPHERAL NERVOUS SYSTEM			
- Paresis			
- Paralysis			
- Sensory Fall out			
- Pins & Needles			
- Urinary retention			
- Reflexes			
22. RESPIRATION			
- Normal			
- Noisy			
- Shallow, weak			
- Painful			
- Assisted ventilation			
- Worsening with decompression			

	COMMENTS	YES	NO
23. CIRCULATORY			
- Pulse			
- Bloodpressure			
- Shock			
- Cyanosis			
24. INJURY			
- Type: - Cut			
- Fracture			
- Position			
-			
-			
-			
- Bleeding:			
- Slight			
- Moderate			
- Severe			
25. Medical Treatment given (attach details)			
26. Status after therapeutic decompression			
27. Residual signs or symptoms (attach details)			
28. Diving Supervisors account of incident.			
29. Divers own account of incident.			
30. Disposal of Diver.			

NOTHING's FOR FREE

Mr Ball, British based managing director of Shell Oil Exploration, has said that his firm is now spending $1500 a minute of their North Sea Oil operations.

A VERY LUCKY DIVER

Keith Momery, a 23 year old skin-diver, became unconscious and sank while diving off Penzance, U.K., recently. His life was saved through the action of Beaky, a dolphin well known to local divers, who swam down and not only brought him to the surface but kept him afloat till rescuers arrived. Not everyone who dives alone can expect such providential succour.

DIVING HISTORY OF AIR EMBOLISM CASES

a. Prospective diver undergoing compression to 10 metres water depth in compression chamber. Over the last 1.5 metres whilst surfacing, started shouting, developed convulsions, dilated pupils. Diagnosis of hysteria made by attending Medical Officer. Given Sparine 65 mgm and Valium 5 mgm IVI. Then surgical emphysema felt in neck.

   Treatment - Therapeutic decompression to 165 feet on Table 5B was attempted at 140 feet 5 inches. Emphysema returned. Patient recompressed to 165 feet on 5E. Then:
   Headache
   Confusion - ? Sparine effect
   Pain chest with deep inspiration
   Absent knee and ankle reflexes.
   Cleared up completely on above. Later re-applied and became a diver.

b. Lost face mask and mouth piece, ditched weight belt emergency ascent. Unconscious and not breathing on surface. Mouth to mouth resuscitation, then sent back underwater for a 10 minute stop, depth unknown. Arrived at Diving School disorientated, upper abdomen and chest pain.
   Treatment - Main chamber occupied and put into one man chamber - later transferred into 8 man chamber. Table I and II - complete recovery.

c. Compressor stopped - emergency ascent. Pain in chest, pains both thighs. No CNS signs. Treatment - Table 1.

d. Man-made equipment, garden hose kinked in upright position, cut off air supply. Pulled off face mask, arrived unconscious at surface. Came to after initial resuscitation. White froth mouth, paralysis R side of face, dilated R pupil absent reflexes.
   Treatment - recompressed 165 feet, Dextran 40 IVI, Plasma IVI, aramine for opnoea and Sodium Gardinal for convulsions. Died in chamber.

e. Dived in Standard Suit. Few minutes down, could not get enough air, passed out. On surface: pain in chest, paresis L arm; bleeding nose. Responded to treatment.

f. Swimming on his back doing shipsbottom search. Whilst underwater developed pain in chest. On surfacing pain in lower back. On O_2 for 4 hours 45 minutes - chest and back pain relieved. Diagnosis: pulmonary barotrauma with air embolism.

g. Dived at 185 feet, developed nitrogen narcosis. Panicked and pulled off face mask. Did an emergency ascent.
   On ascent: paresis R side, aphasia.

h. Dived to 12 metres for 20 minutes. Did a controlled ascent. Ran out of air and rebreathed from set then continued controlled ascent. Air bubbled from mouth on reaching surface.
   On surface: After 2 minutes pain in lumba area. Seen and diagnosed as lumba strain by inexperienced Medical Officer.

   4 hours after dive: severe lumbar backache. Paresis ++ lower extremities - could not straighten leg due to pain. Urinary retention.

   Treated at 18 metres on long O_2 table (4 hours 45 minutes). Pain in back gone after 6 minutes. Passed urine completely after 3 hours 5 minutes. No sequela after treatment.

i. Bought a SCUBA set. Practised controlled ascents for 30 minutes. Depth 40 feet. Symptoms: Pain L shoulder after dive. Very severe next day on arrival at Diving School. Treated on Short Oxygen table 2 hours 15 minutes. Pain gone after 6 minutes.

k. Snorkel diving. Buddy breathed from a scuba diver. Chest felt uncomfortable and shot to surface.

On surface: Immediate chest pain. Nausea, frontal headache, severe tiredness, with now prominent nausea. Seen 4 days later by a doctor who diagnosed muscle injury. Tanderil given.

5 days later coughing up blood and severe chest pain. Chest x-ray clear. Diagnosis of sinus barotrauma made. Two days later: worsening of frontal headache and chest pain. Still vestibular symptoms. Diagnosis of pulmonary barotrauma made by a diving Medical Officer. Treatment O_2 at 18 metres. Improvement after 10 minutes, completely pain free after 15 minutes. Surfaced after 2 hours 15 minutes. No sequela.

l. Dived at 70 feet for 17 minutes. Swam up trying to keep pace with an expanding bubble.

On surface: Got out of water feeling fine. After 3 minutes became dizzy and disorientated and blind. Put onto 100% O_2 immediately, taken to Diving School. On arrival vision 100%. Nausea, headache and breathing pain R chest. Started on O_2 at 18 metres. Still nausea, headache and vomiting after 3.5 hours. Dextrostix: 40 mg% blood-sugar. 10cc of 50% Dextrose IVI with immediate relief of symptoms. Surfaced after 4 hours 45 minutes with NO symptoms and signs. Chest X-ray NAD and a glucose tolerance test arranged.

5 hours after decompression: diver unconscious, roused with difficulty, disorientated. Paralysis from waist down. Sensory fall-out from waist down. Taken down to 60 feet and another shot of Dextrose given IVI. Diver conscious, only paresis of lower extremities. After discussion with Surg Cdr Pearson RN: Table 65 (air 165 feet). On arrival - headache better but again complete paralysis lower extremities.

Medical Treatment:
1. Dextran 40, 500 ml IVI over half hour, repeated 6 hourly.
2. Decadron 100 mgm IVI 6 hourly.
3. Heparin 5000 µ subcut 8 hourly.
4. Lasix 20 mgm IVI.
5. Maxolon 2cc IVI stat.

Had to be catheterized after 5 hours for urinary retention.

Condition steadily improved until at 30 feet. Then complete paralysis both legs again. Patient put onto a modified O_2 table with complete relief. On surfacing after 46 hours, severe atoxic walk which cleared over next couple of weeks.

Three months after accident - NO neurological residual and declared fit for diving again. Patient however has lost his nerve (perhaps not surprisingly!).

A PAPER SUBMITTED TO BAROLOGIA - THE SOUTH AFRICAN SOCIETY FOR UNDERWATER SCIENCE

MTT Davies, BSc MSc

ABSTRACT:

THE ADAPTATIONS FOR AND THE EFFECTS OF DEEP DIVING ON VARIOUS VERTEBRATES

Various physiological and anatomical features of diving vertebrates (mainly mammals) are cited, many of which are compared with those in man. The sperm whale can dive to 1134 m and remain submersed for up to 75 minutes. As in other diving vertebrates, the whales have important modifications of their blood systems, lungs and muscles, which enable them to stay submerged at depth for long periods of time. The advantages of an oblique diaphragm, small lung volume, pronounced Bohr shift, high muscle myoglobin content, depression of metabolic rate with circulation re-routing are some of the aspects discussed. The effects of high pressure are also mentioned.

INTRODUCTION

The aim of this paper is to bring to light some of the more important physiological and morphological features of diving forms and how these features come into operation during a dive. Comparisons are made with man and other terrestrial vertebrates.

Most of the mammal divers include the whales, dolphins, seals, dugong, manatee, walrus and sea-lions. Examples of diving birds are the penguins, puffins, ducks, cormorants and gannets, and of reptiles, the Galapagos iguana, turtle and crocodile.

Apart from the necessary prerequisites of general body form ie. the development of a torpedo-shaped body for reducing drag forces in dolphins, and a powerful fluke, or tail, for propulsion in whales and dolphins, three features are of prime importance to these diving forms. These are specialisations within the lungs the muscles and the blood. The cardiovascular and closely related respiratory adjustments have in fact extended the niches of all vertebrates, and in the case of those entering or leaving an aquatic environment, we find some incredible responses. Before elaboration on these responses, we should look first at just a few divers and the depths and times observed for their dives (Table I).

TABLE I
OBSERVED DURATION AND DEPTH OF DIVING IN SOME VERTEBRATES

	TIME (mins)	DEPTH (m)
Emperor Penguin	18	265
Grey Seal	18	128-146
Weddel Seal	43 (max 70)	600
Blue Whale	50	500
Sperm Whale	75	1,134
Bottle Nose Whale	120	300
Bottle Nose Porpoise	5	300
Most Men Resting	2	
Active	1	
Experienced skin divers	2.5	61
Record for man		73

After Gordon, MS, 1972
Harrison, RJ and Kooyman, GL, 1971

We can now consider adaptations of the lungs, muscles and blood separately. When these factors have been described, estimated dive times can be made, and compared with the observed dive times shown in Table I.

Discussion

1. LUNGS

One might well expect air breathing vertebrates to extend their dive times by having larger lung volumes per unit body weight compared with their terrestrial counterparts, so that an equivalently larger amount of oxygen is released to the tissues. This, however, is not the case - the lungs of some divers being the same proportional volume as non-divers, as in seals, or being half the volume of non-divers as in the case of whales. Scholander suggests that the lungs of whales may collapse during descent because they do not have a firm attachment to the thoracic wall - the air in them being forced into the dead air spaces (ie. a strengthened trachea), where gas exchange does not take place - the advantages of this will be discussed later.

Although the lungs are similar in size or smaller than those of man, the tidal volume and the percentage utilisation of oxygen is higher. See Table II.

TABLE II
LUNG VOLUME, TIDAL VOLUME AND PERCENTAGE OXYGEN UTILISATION IN SOME DIVING MAMMALS AND MAN

	LUNG VOL L/100 Kg	TIDAL VOL L/100 Kg	$\%O_2$ UTILISATION
Seal (Phoca)	5.0	1.8	5.0-7.0
Porpoise (Phocaena)	6.6	5.9	8.0-10.0
Bottle Nose Whale	2.5	2.2	8.0-10.0
Fin Whale	2.9	2.5	8.0-10.0
Man	5.0	0.8	4.0-5.0

2. Muscles

An important feature of diving vertebrates is the large quantity of myoglobin contained within their skeletal muscles. Compare for instance the myoglobin content of seal muscle with that of a cow, and we find the former contains 7715 mg myoglobin/100 g tissue whereas the latter has only 1084 mg myoglobin/100 g tissue.

Larger quantities of myoglobin are also fouled in birds such as grouse, which fly only short distances but do it very quick]y, the advantage as to these birds, and to diving forms, is that the increased myoglobin levels provide a very important oxygen reserve within the muscle - as will be seen in the next section.

3. Blood

There is a tendency for the blood volume and its oxygen carrying capacity to be greater in diving vertebrates than in man and other terrestrial vertebrates. As shown in Table III.

TABLE III

BLOOD VOLUME AND OXYGEN CARRYING CAPACITY OF THE BLOOD OF SOME DIVING AND NON DIVING SPECIES

	BLOOD VOL/% BODY Weight	O_2 CARRYING CAPACITY VOL%
Penguin	9.0	20.0
Seal (Phoca)	15.9	29.3
Porpoise (Phocaena)	15.0	20.5
Sperm Wale	-	29.1
Rabbit	6.5	15.6
Hen	3.9	11.2
Man	6.2 - 7.0	20.0

After Gordon, MS, 1972.

This obviously results in larger quantities of oxygen being taken down during the dive, and in a more rapid expulsion of CO_2, so that after emergence there will be a rapid recovery and the animal is ready to dive once again.

These diving forms also have a more pronounced Bohr shift. This means that the oxygen dissociation curve moves even further to the right than in the case of the terrestrial vertebrates. The advantage of this being that with the increased levels of carbon dioxide and the reduced pH during a dive, more oxygen is unloaded from the haemoglobin at the same O_2 tensions. This shifting to the right of the oxygen dissociation curve with the resulting straightening of the curve, means that the oxygen is made available to the blood at higher carbon dioxide concentrations. In effect, more use can be made of the O_2 that is available.

FIG. 1.

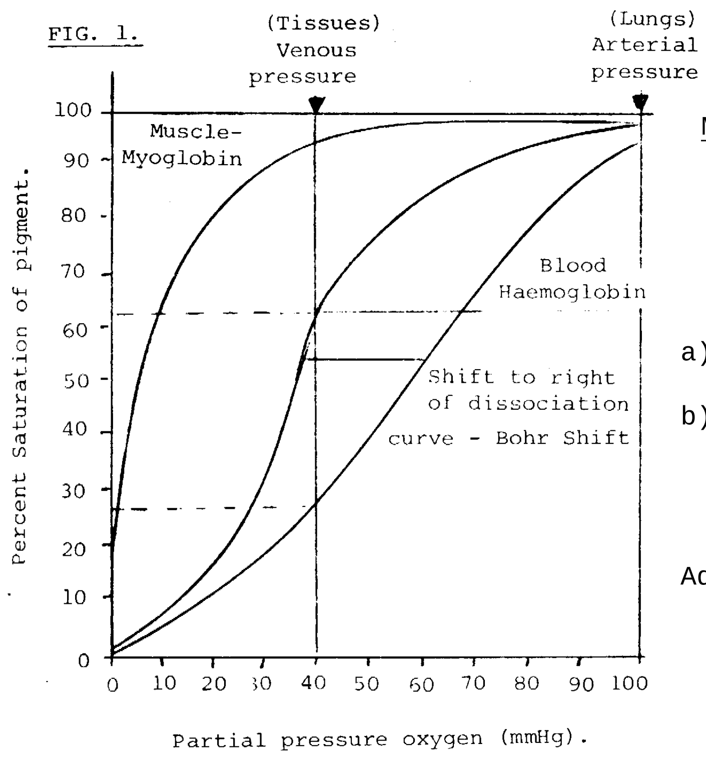

FIGURE I

OXYGEN DISSOCIATION CURVES FOR MAMMALIAN MYOGLOBIN AND HAEMOGLOBIN AT BODY TEMPERATURE

a) = 3mmHg PCO_2 & pH 7.6

b) = 40mmHg PCO_2 & pH 7.2

Adapted from Hoar WC, 1966.

The dissociation curve for myoglobin, unlike the sigmoid one for haemoglobin, is hyperbolic, and well to the left of the former.

This means that although oxygen is rapidly taken up from the blood, it is only released at very low oxygen tensions, or partial pressures, so that when the muscles are being exerted, as during a long dive, there is a good supply of oxygen available. Myoglobin, especially when at the high levels found in diving forms, therefore provides a very important, and quick, supply of oxygen when there is little available from the blood. See Figure I.

If we now look at Table IV, we find that the estimated dive times fall far short of the observed times, It can therefore easily be appreciated that diving mammals and birds can stay submerged far longer (up to 6 times as long in the penguin) than if they continued to consume oxygen at their normal pre-dive rate.

TABLE IV

COMPARISONS OF SOME OBSERVED DIVE TIMES WITH ESTIMATED DIVE TIMES

	OBSERVED DIVE TIME (Mins)	ESTIMATED DIVE TIME (Mins)
Penguin	18	3
Seal	18	6
Bottle Nose Porpoise	5	3
Bottle Nose Whale	120	36

The anatomical and physiological adaptations described clearly therefore do not give the full story. What further effects has evolution to an aquatic and diving existence had on these forms and how do these effects come into play?

The following will be considered:

- Bradycardia
- Lactic acid tolerance
- Circulation re-routing
- High pressure adaptations

Bradycardia

Non-diving vertebrates, such as man, have the necessary “equipment” to show a diving response, but it is nowhere near as specialised as in the diving forms.

It is generally accepted that there is a depression of the metabolic rate during a dive so that oxygen is conserved. Paul Bert (after Gordon MS, 1972) made one of the earliest observations of bradycardia, this being the lowering of the heart rate, during submergence experiments with ducks.

The Bradycardia response was soon afterwards shown to be of vagal origin, for when this nerve supply was sectioned the response was eliminated. Diving animals studied after this, have always shown the effect (Andersen, HT, 1961, 1964. Scholander, PF, 1940).

To demonstrate how much better at bradycardia the divers are than man we can use the Grey Seal as an example. This animal can reduce its heart beat from 130 bpm to 4 bpm after only one minute during a dive. Man, depending on such factors as age, diving experience, temperament of the individual, water temperature and so forth, can lower his heart rate by only a half.

Circulation re-routing

Another very important feature of the diving vertebrates mentioned, is the ability to circulate blood only to those tissues that are important during a dive, and reduce it or cut it off from those that are not.

Most work on the effects of diving on the vascular system has been done on pinnipeds (after Harrison, RJ, and Kooyman, GL, 1971), and circulation re-routing has been demonstrated by injections of a radioactive rubidium compound into the blood.

The pectoral, gastrocnemius and neck muscles, as well as the skin of all the body except the head, which must be kept warm, have the blood supply cut off. A cut-off of supply to the skin is important for conserving heat which is more readily lost to water than air, especially in the colder depths. There is also cessation of supply to the renal and gastro-intestinal regions. In the case of the latter, the oesophagus is supplied because it must function for the swallowing of food.

The adrenal and thyroid glands and brain, however, have an increased supply, and the liver, heart and eye muscles a normal supply.

The site of vasoconstriction is unusual and characteristic in diving forms (eg. ducks and seals) for instead of the arteriolar constriction characteristic of non-divers, it is the larger arteries that constrict by innervation from the sympathetic nervous system. The advantage of this is that there can be no chance of peripheral dilation of vessels by the over-riding effects metabolic dilators can have on the sympathetic nervous system (ascending dilation), because the centre of control is further back than the site of production of the local dilator factors.

A change in blood pressure, which could be disastrous, does not take place, as Elsner et al. (1966) have shown with the sea-lion. The central arterial pressure does not change, because the high peripheral resistance is balanced by a low run-off rate of blood.

Lactic acid tolerance

Work done on the seal (Scholander, PF, 1940. Andersen, HT, 1969) has shown that the lactic acid level rises only slightly during the dive, but increases by nearly ten times after emergence (Figure II). This is almost certainly because the lactic acid is stored in the muscles in consequence of restriction of blood flow, and then released upon return to normal circulation. As well as tolerating low O_2 and high CO_2 levels, high lactic acid levels are also tolerated.

Clearly, oxidative metabolism is limited in most tissues because of vasoconstriction. It is also further restricted, and the vital oxygen conserved, because of the predominance of anaerobic pathways in the periphery.

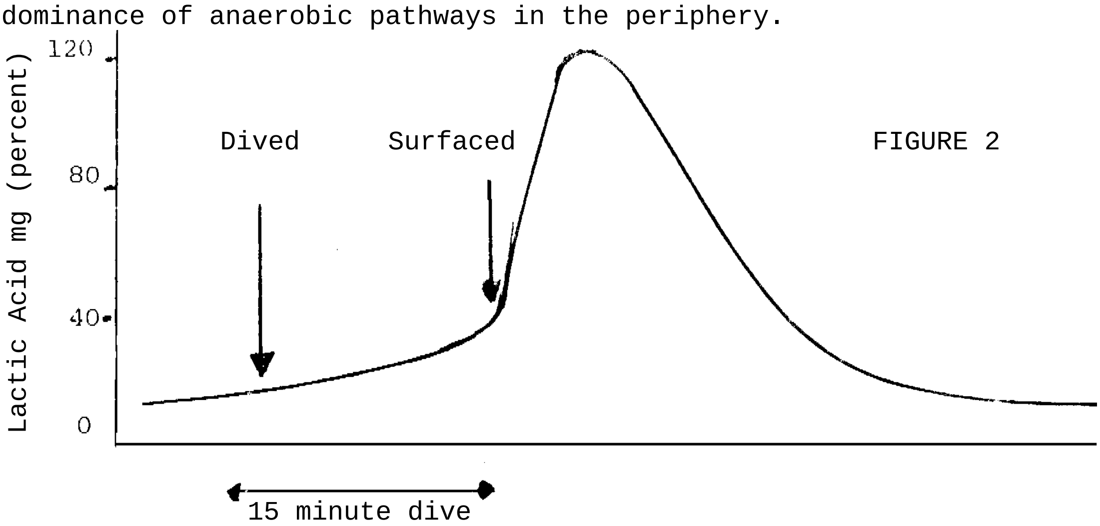

FIGURE 2

Lactic acid level in arterial blood of a seal before, during, and after a 15-minute dive (after Andersen, 1969).

The Weddel seal can stay beneath the ice for well over 60 minutes. Kooyman (1969) and Peak et al. (1970) have shown that the lactate dehydrogenase isozyme complex of its muscles is involved with this anaerobic tolerance. The LDH5 is orientated towards pyruvate reduction, and its concentration is 30% higher in the muscles of the Weddel seal than in the less efficient diving, Cape Fur seal. Consequently, the greater amount of its present, the more oxygen will be spared by the muscles (the largest body tissue), and there will be an extended period of availability of this oxygen for aerobic respiration elsewhere.

High pressure adaptations

As depth increases, the hydrostatic pressure increases at a rate of approximately one atmosphere for every ten metres of sea water. Within the diving mammal therefore, air spaces such as the lungs and middle ear tend to collapse and there are modifications which permit these internal gas spaces to remain in equilibrium with ambient pressure. For instance, the thoracic wall is flexible and the diaphragm oblique, thus permitting abdominal blood and viscera to displace the diaphragm into the thorax. Also, the linings of the middle ear space contain sinuses, which become engorged so reducing the volume of the space when it is under pressure.

Finally, there is no danger of nitrogen narcosis upon the rapid decompression during a fast ascent, for the following reasons: when the lungs become compressed, air is forced into non-respiratory spaces so little nitrogen can enter the blood, next there is a low lung volume, and finally, because nitrogen is more soluble in fatty substances, it is thought that much of it enters the copious quantity of fatty tissue found for example, in the blubber of whales.

Conclusion

Diving appears therefore, to be a special case in which mechanisms of widespread occurrence have been elaborated to the extreme. Modifications of lungs, muscles and blood, with tolerance to high carbon dioxide and lactic acid concentrations, as well as a pronounced slowing of the heart beat, are some of the accomplishments that have resulted in the successful invasion, by air-breathing animals, of aquatic environments and have extended the vertical range of mammals to over 1000 metres below the surface of the ocean.

To quote Gordon:

> “Such adaptations also make possible the rather startling observations of SCUBA divers on the coasts of the Galapagos islands, where they encounter the rather improbable spectacle of marine iguanas, happily grazing on algae at depths in excess of 10 metres in the company of a host of fishes!”

* * * * * * * *

S W A L K

Brigitte Bardot has presented her pet 4 month old seal to the French Riviera's Marineland. She did this, she said, for the animal's own good. The seal was given her by Brittany fishermen who had found the deserted pup in Newfoundland. But the change to Marineland was followed by a severe psychological setback. Apparently the seal had become accustomed to a routine of bottled milk, fish soup and kisses from BB. Heaven preserve us from being done good with to such a set up!

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DIVING ACCIDENTS - NORTH SEA OIL AND GAS INDUSTRY, 1971-1975

We all know that diving is a hazardous business, but there is no doubt that the number of accidents that have been encountered, in particular in the offshore industry, is far too high. The United Kingdom Government has appreciated this and has introduced legislation to try and improve the situation.

However, this particular discussion paper is not designed to deal with legislation but, as a point of interest, I will tell you that the United Kingdom is drafting a common set of diving regulations which will include the existing Factory Acts, Offshore Installations, Submarine Pipelines and some of the Merchant Shipping Regulations.

Within the United Kingdom all fatal and serious diving accidents have to be reported to the appropriate Government Authority immediately. All fatal accidents are then investigated by the Government Department concerned and the police. For example, in the offshore industry, as soon as information is received that a fatal accident has occurred a diving inspector immediately proceeds to the site of the accident. Almost invariably one meets up with a team of police investigators on the way. The accident is then investigated on site. Statements are taken, details of the techniques employed before, during and subsequent to the accident are recorded. Copies of all records are taken, gas samples and where applicable the equipment is taken away and sent to the Admiralty Experimental Diving Unit for investigation. The body of the deceased is taken to the mortuary for the pathologist to do his work. This part of the investigation is almost invariably assisted by the doctor concerned who is called out for the particular emergency.

The next step almost invariably is to discuss the details of the accident with the pathologist.

I then co-ordinate all the results of everybody’s investigations and provide a full report. This report is then forwarded to the appropriate Procurator Fiscal or Coroner to help him to conduct his Public Inquiry.

At the eventual Fatal Accident Inquiry in Scotland or the Coroner’s Court in England all the details are made public, anybody concerned can be legally represented if they wish, including the next of kin, and any member of the public can purchase a transcript of the proceedings. Our aim is to ensure that every relevant detail is brought out at this Inquiry.

If however, during the investigation anything comes to light which might indicate the method of saving life in the future or preventing accidents, this information is immediately distributed to all diving companies and interested parties. We are also fortunate in that we have the full support of the RN Medical Services and can call on their assistance in our investigations.

At present the reporting system requires only fatal and serious accidents to be reported but this does include bends. It is sometimes difficult to differentiate between a “serious accident” and an “accident” with diving and in the future we shall require immediate reporting of fatal and serious accidents and periodical reporting of all other accidents including cases of decompression sickness. I am pleased to say, however, that diving companies operating offshore are very forthcoming with details of all their incidents.

I don’t wish to anticipate any discussion on Central Registries for the collection of diving data but I must state that it is difficult to detect a trend in accidents either from the physiological side or from the equipment side unless one has the complete picture. Without the full picture, it is difficult for diving companies to avoid certain incidents and even more difficult for Government to introduce legislation to cover a particular problem.

I propose to concentrate now on the fatal diving accidents that have occurred in the offshore industry in all sectors of the North European Continental Shelf.

Some of the older records are unfortunately lacking in detailed information.

The first fatal accident recorded in the Department of Energy records happened to a diver in February 1971. He was diving in the Norwegian sector to a depth of 200 feet without a diving bell. The cause of death was drowning.

A month later from the same installation Diver No 2 diving to 200 feet with a diving bell died to decompression sickness. The actual details of these two accidents are rather scarce.

In November 1971 Diver No 3 died after a dive of 275 feet from the drill ship Glomar 3. My broad interpretation from the available records is that the diver carried out a dive to a depth of 275 feet for a bottom time of well over 45 minutes. He had previously carried out a dive to this depth within the preceding 24 hours. Having completed his task at the bottom he started his ascent and his lifeline or airpipe reportedly became fouled. It would appear that during the process of clearing himself he became free and he blew to the surface. The pathologist’s finding was that this diver died from embolism.

In May 1972 Diver No 4 was lost from the rig Britannia during a dive to 44 feet. The cause of death was drowning and at the subsequent Coroner’s Inquest, grave doubts were expressed as to whether the deceased had in fact been trained as a diver and whether he was qualified.

In August 1973 Diver No 5 died of pulmonary haemorrhage whilst diving to a depth of 320 feet. Scientific evaluation of the breathing equipment subsequent to the fatal accident led to modifications.

In December 1973 No 6 disappeared whilst diving from Blue Water 3 and the body was not recovered. The task he was required to do was simple and the depth was only between 60 and 70 feet. He was an experienced diver and for some reason or other cut his communication lifeline and was lost. At the time of the inquest the only logical conclusion that could be drawn was that for some reason or other the diver got into a panic. However, we know that he was cold and shivering as a result of a previous dive and our subsequent investigations of the effect of cold on the diver suggest that he might in fact have carried out his illogical actions during the onset of hypothermia. This can only be surmised in hindsight but I am prepared to say that everything points to the fact that cold is a very real menace and may well trigger off other problems.

In January 1974 two divers (Nos 7 and 8) operating from the drill master rig in the Norwegian sector at a depth of 250 feet lost their lives when the bell accidentally surfaced. Subsequent investigation showed a breakdown in company communications correcting the drill after a modification to the weight slipping devices.

In April 1974 Diver No 9 was drowned whilst diving from a drill ship Habdrill at a depth of 300 feet. This was an unfortunate case of panic by the attendant in the bell. The diver was carrying out the first operational dive from Habdrill on that particular site. The diving team had carried out several practice dives and they were very enthusiastic to get down to work. This may have had some bearing on the accident which really started when the diver overworked. He carried out his task in almost record time and in spite of the fact that he was advised several times to slow down. Having overworked on the task the diver was in some distress and swam rapidly back to the bell, but unfortunately he took a turn around one of the bell's weight wires with his umbilical. The bell assistant tried to assist him into the bell by pulling on his umbilical which in turn pulled him under water. A series of panic actions by the attendant led to him cutting the diver's umbilical and shutting the bottom door and screaming to the surface to be brought up.

In June 1974 Diver No 10 got into difficulties whilst diving to a depth of 200 feet from a pipe-laying barge. He was surfaced and carried out a surface decompression routine albeit one that was well outside the normally accepted 5 minutes technique and died from decompression sickness. The eventual postmortem showed that the deceased was suffering from heart and respiratory diseases. He was also obese.

In July 1974 Diver No 11 died from a pneumothorax after a dive of 492 feet. This particular fatality was well publicised in Britain at the time because the doctor concerned failed to diagnose a pneumothorax.

In August 1974 Diver No 12 was lost while diving in a bell from an installation in the Norwegian sector. He collapsed and died from anoxia. Failure in communications when ordering the gas, and an error by the supervisor in failing to test the gas, led to the diver being fed pure helium.

In October 1974 Diver No 13 died whilst carrying out a surface swim from the installation Waage 1. At no time did he dive below the surface. The subsequent postmortem showed that he died from drowning aggravated by vomit and that he also sustained broken ribs. It is difficult to categorise this as a diving accident and even more difficult to state how the diver sustained his broken ribs and, in fact if they were the cause of his drowning. However it is possible that he may have struck the sponson or the "cow catcher" in the swell.

In October 1974 Diver No 14 was lost while operating from a bell in the Norwegian sector. The fatality occurred due to a breakdown in communication between the divers in the bell and the control on the surface. This lead to a temporary switching off of the diver's gas supply and when realising that he had lost his main gas supply, the diver rushed back to the bell but became fouled on the way.

In December 1974 Diver No 15 operating from an installation in the Irish sector of the Celtic Sea was lost through asphyxia. He was carrying out a dive from a bell in bad weather and it would appear that the movement of the bell sheared his umbilical on some obstruction. For some unknown reason the diver did not use his emergency gas supply. The weather was cold and the diver had no artificial heating and once again one cannot help thinking, in hindsight, did cold play an important part in this accident?

In December 1974 diver No 16 operating in the sheltered waters of Scapa Flow to a depth of 100 ft was trapped in a pipe by suction. It would appear that a pipe on the pig trap of the pipe was damaged, probably by the jet sledge or the anchors of the barge, and the diver displaced the vale causing a massive suction which partially sucked his shoulder and arm into the pipe.

In March 1975 a Norwegian diver died whilst operating to a depth of 460 ft from the Borgny Dolphin in the British sector. There was no doubt that cold played an important part in this particular accident. We know that the diver made himself heavy to operate on his tasks. We also know that he was swimming at the job. He worked rapidly and refused to take the advice of surface control to slow down his operations. The cause of death was anoxia but it is difficult to establish how one can die from anoxia when the breathing gas contained more than adequate oxygen and the equipment was working satisfactorily.

We know that hard work increases the O_2 uptake. We know that shivering can increase this uptake by as much as 100%. We also know that the onset of hypothermia causes respiratory and cardiac systems to behave abnormally. I believe that a combination of these three things can lead to fatalities such as the one I have just described.

In March 1975 diver No 18 died during or soon after a dive to 240 ft operating from a gas platform in the southern north sea. The cause of death was pulmonary oedema caused by cardiac myopathy and the Coroner brought in a verdict of natural causes.

In June 1975 a diver was lost from a barge in the Norwegian sector. This accident is still being investigated by the Norwegian authorities and I cannot say any more than that.

In July last year two divers were lost on a pipe suction accident. The accident occurred in 120 ft of water and it was clear that the real problem of differential pressures was not fully appreciated.

In September last year two divers were lost after a successful dive to 390 ft. Having completed their dive with no problems the divers locked through into the main living chamber. This chamber was heated to between 110° and 120°F and due to a series of errors this temperature was probably increased and the divers were unable to get back to the transfer under pressure chamber to cool off.

In the past, particularly in the North Sea, the emphasis has always been on keeping the diver warm. It now becomes obvious that care must be taken to keep the diver in thermal balance at both ends of the spectrums.

In 1975 a fatality occurred in Stavanger Fjord during the construction of a Condeep platform. The diver dived to 140 feet and for some unknown reason slipped his helmet and umbilical and disappeared. Subsequent enquiries into the background of the deceased suggest that there was a lack of basic training.

Again in 1975 a fatal accident occurred in the Dutch sector of the North Sea when a diver operating in comparatively shallow water on air cut his lifeline; he floated to the surface and then sank and was not recovered.

In January 1976 a diver was drowned when operating a depth of 480 feet and it is possible that he accidentally switched off his own gas supply by knocking the ball valve control.

Again in January a diver was lost through pulmonary Barotrauma when a diving bell accidentally surfaced. His bell companion in this particular accident was also seriously injured.

In May a diver was drowned whilst operating in 120 feet due to the fouling of his umbilical.

Another diver died from Pulmonary Barotrauma after a dive to 120 feet in Loch Fyne. Diver No 30 was lost through drowning whilst diving on air at a depth of 120 feet off Anglesey.

Diver No 31 was lost whilst operating from a barge in the North Sea almost certainly due to his main gas supply becoming disconnected at his mask.

Time does not permit me detailing all the other accidents and near misses but from the information that we have, an initial analysis of figures suggest a broad breakdown of the reasons something like ...

Human error	16	Lack of equipment	3
Poor physical condition	3	Inadequate medical supervision	2
Inadequate training	6	Poor diving supervision	6
Equipment failure	9	Poor equipment maintenance	4

In addition cold has certainly been a contributing factor in at least three and probably more cases.

Reports have been received as a result of accidents and also through the grape vine of divers becoming unconscious under water for no apparent reason. The Department of Energy has instituted a research project to investigate this particular problem.

In addition to the introduction of legislation the Department of Energy now issues diving Safety Memos on points of diving safety as soon as they arise. One in particular applies to the topic for this paper and that is Diving Safety Memo No 14 which draws attention to the need to provide a hoisting harness for the diver which lifts him from the pelvis as opposed to the chest or shoulders.

Carelessness Kills more than we do !"

BAROTRAUMA OF ASCENT?
A SUBJECTIVE ACCOUNT OF A PERSONAL EXPERIENCE

With borrowed equipment the diver entered the water with two companions and began to follow a sloping coral-studded terrain. He had no contents gauge or depth gauge and no buoyancy vest. His mask was leaking freely and the flash gun he carried was not only not working but was giving him small shocks. These annoyances irritated him to the extent that he was frequently clearing his mask in an unnecessarily violent manner.

Approximately 30 minutes after starting the dive he cleared his mask once more, emptying his lungs to do it and tried to inhale on an empty tank. His companions were close by but outside his reach and not looking at him.

The diver looked up, estimated he was 50 or 60 feet from the surface and decided to make a free ascent. He felt that he was in control of the situation and kept his regulator in his mouth hoping that he might get some air out of his tank as the pressure grew less and consciously tried to relax his glottis so that he could exhale.

All seemed well until he was about 20 feet deep, when his regulator seemed to explode out of his mouth and then he found himself on the surface, not knowing how he got there.

He was in extreme respiratory difficulty seemingly only able to inhale a few ccs of air, and having to shout with every exhalation. He was kicking madly to keep his mouth just above water and such was his conscious state that he clung to his camera and made no attempt to let go of his weightbelt or tank.

Luckily for him his companions came up and assisted him to shore, all this time in desperate respiratory difficulty. When he sat down in shallow water he coughed up a little clear froth and his respiration suddenly became normal, and apart from being extremely tired he felt quite well.

After lunch he went snorkeling and was diving down to 20 feet with no trouble. This story is a classic example of bad diving procedure - AN AWFUL EXAMPLE!

But the pathophysiology puzzles me. *Why did the respiratory difficulty reverse itself so suddenly? And why no after effects?*

VICTOR BRAND

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POTS NOT NATURAL HABITAT?

There is an interesting case simmering up in Newcastle at present. A man has been charged with stealing lobsters from another man's pots. As his defence he has claimed that the lobsters are the property of whoever first lifts them from the water, being still wild animals "free for the taking" until the owner lifted his pots. It was also claimed, naturally, that the State had no jurisdiction as the action occured beyond the high water line. Legal evidence was offered to the effect that larceny could be committed on wild animals that are fit food for man. Sergeant Richards assured the Court that it is undisputed that lobsters are fit for human consumption. There is no mention of the fate of the lobsters pending the resumption of Court hearings ....

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BRIEF NOTES ON 16 CASES TREATED AT THE UNIVERSITY OF MICHIGAN HYPERBARIC UNIT

Professor Martin J Nemiroff

In Michigan we average 3 to 5 Scuba diving deaths a year and many non-fatal accidents are reported, often by hearsay rather than by written reports. The following cases presented at our chamber for treatment over a two year period. I will briefly outline the circumstances and my own interpretations, based on available information. There were 7 cases of Air Embolism and 7 of decompression sickness among these non-fatal diving incidents.

A. Air Embolism and Pulmonary Barotrauma

CASE 1 46 year old male making a controlled free-ascent in a quarry at the correct speed, with an instructor in attendance. He was a 3 pack-a-day smoker and had bronchitis. He suffered pulmonary barotrauma with subcutaneous emphysema. No treatment was required beyond a period of observation.

CASE 2 46 year old male, surfacing correctly from 80 feet in a large lake, became suddenly paralysed and had loss of vision. He was treated 6 hours later with complete recovery. He had a repeat experience one year later, with the same symptoms. This suggests either a small ischaemic area in the brain or a repeat air embolism. Second treatment also was successful.

CASE 3 27 year old man suffered chest pain and obtundation after making a struggling ascent from 15 feet in a swamp. He did not exhale while being hauled to the surface, it was stated. Chamber treatment was successful.

CASE 4 31 year old male performing ditch-and-don manoeuvre in a pool. He suddenly surfaced with subsequent pupil dilatation and taxia. Treatment in the hyperbaric chamber was successful.

CASE 5 32 year old male was doing a “NAUI-bailout”. This involves jumping into a pool with all equipment in one’s arms and donning it underwater. He developed extreme headache and decreased visual acuity. The provisional diagnosis was of air embolism but subsequently I felt that he had suffered a sphenoidal sinus squeeze. Symptoms resolved when he was pressurised.

CASE 6 This 15 year old scuba student reported substernal chest pain and dyspnoea following a pool scuba lesson. Chest X-Ray revealed pneumo mediastinum. This resolved without necessity for treatment. The diagnosis was made not by the primary physician but by the later X-ray.

CASE 7 This 27 year old advanced scuba student, practicing buoyant emergency ascents while buddy breathing, had an episode of panic and separated from his buddy. He ascended rapidly without exhaling. Subsequently, severe headache, substernal chest pain and shortness of breath occurred. He presented 5 days later, improved. No treatment was then required. The impression was gained that this quarry diving incident had caused a cerebral air embolism in association with pneumo mediastinum and a minimal pneumothorax.

CASE 8 This 27 year old male was an advanced diver practicing free ascents in a lake. On the first attempt from 60 feet he surfaced exhaling but on the surface he convulsed and became comatose. He had fixed dilated pupils on admission and suffered cardiac and respiratory arrest on arrival. He had been betting beers on who could surface with least speed and least “popping out of the water”. He lost! He was pressurised 1.5 hours later and had an excellent recovery. He had suffered cerebral air embolism, pneumo-mediastinum, bilateral pneumothoraces and subcutaneous emphysema. Incidentally, he was a 1-1.5 pack per day smoker with a chronic 2 year productive cough.

CASE 9 This boy of 18 took "PCP" (a horse tranquilliser), put on a scuba tank and made a solo dive in a 110 feet deep lake. He exited the water on the opposite side, fell off the dock backwards and plunged into the water. On recovery he had unequal pupils, nystagmus, and reflex asymmetry in knee-jerk testing. Recovery was complete after recompression (which was very eventful). Diagnosis was not clear since "PCP" causes many of the same symptoms and signs as observed here.

B. Decompression Sickness Cases

CASE 10 This 31 year old wreck diver did not follow decompression tables on two successive dives to 150 feet for 20 minutes. He thought that breathing oxygen on the surface was enough protection. Spinal cord decompression illness resulted: recovery was complete after recompression and three months of physical therapy.

CASE 11 This 26 year old female diver made successive decompression dives on a wreck. Although she followed the tables religiously she was maximally exerting herself and the US Navy Tables are designed for males at intermediate levels of exercise. She suffered wrist pains (in a previously injured joint) and progressed to shoulder pains. Recurrence of symptoms during "ascent" in the chamber necessitated an extension of treatment.

CASES 12 AND 13 were two wreck divers with joint pains on surfacing from 110 feet. The first diver had spent 20 minutes at this depth on each of two dives.

CASE 14 Caisson worker, aged 35, presented with pain after working a double shift and then decanting out without decompression.

CASE 15 This 31 year old wreck diver ran out of air and did a buddy breathing ascent to 60 feet, then a free ascent to the surface. This followed a 20 minutes bottom time. He developed paresthesias and numbness of both arms which cleared on recompression therapy.

CASE 16 A "hard-hat" diver developed severe pulmonary symptoms and elbow pain after surfacing from 110 feet following a bottom time of 70 minutes. He had severe skin, joint and cardiovascular symptoms which required recompression and extreme supportive measures.

In summary, these cases are of diverse aetiology and probably represent only about one quarter of the cases that occur. The following comments are offered:

a. Inexperience or lack of training, including poor judgement, is a factor despite all these divers being certified.

b. Poor physical health may be present, eg. heavy smoking and chronic bronchitis was noted in two cases.

c. In one case a female followed a dive profile not suitable for females.

d. Drug intoxication with "PCP". Many had alcohol within the preceding 24 hours.

e. Open water "free ascents" are inherently dangerous.

Our divers dive in deep, poorly illuminated, cold waters. Excessive cigarette smoking alcohol and drug intoxication are serious problems and further reduce the safety margin.

CLINICAL EXPERIENCE WITH A SINGLE PATIENT HYPERBARIC CHAMBER

Gavin R Dawson, DA, FFARCS, FFARACS *

This paper summarizes practical experiences with the first 100 cases treated in a single patient Hyperbaric Chamber at Prince Henry's Hospital, Melbourne.

The Unit, generously donated by the William Duchland Foundation in 1960, is a Vickers RHS/3 Radiotherapy System which utilizes a high flow oxygen supply with no recirculation.

The chamber is 7 feet in length with an internal diameter of two feet. The walls are double layered methylmethacrylate with an interface of air. Oxygen flow rates vary between 250 and 400 litres per minute.

Advantages of this single Unit are:

1. Relatively Cheap Installation. The Unit is located in a small room at the far end of a general surgical ward.

2. Low running costs. Oxygen is taken from the Hospital's Liquid Oxygen supply. At the current rate of $12.30 for 100 cubic metres, 2 hours of therapy costs no more than $4.30.

3. The whole body is visible and immersed with oxygen. The patient does not have to endure the discomfort of a mask and it is ensured that the highest concentration of oxygen is inhaled at all times.

4. Minimal risks to attendants. There are no problems with medical attendants enduring the effects of pressure or nitrogen within the Unit.

Patient Comfort

Practical problems of patient therapy involve - apprehension, boredom and sheer claustrophobia. Light sedation is often administered for the first treatment but simply psychology of explanation and reassurance is more effective. Boredom is relieved by a radio transmitted through the chamber intercom circuit and claustrophobia is a more difficult problem involving tact and strong persuasive powers.

COMPLICATIONS

1. Effects on the Ears

Ear discomfort is reduced by slow pressurisation and Valsalva manouvers performed by the patient. No myringotomies are undertaken and severe aural dysbarism is relieved by suddenly dropping the chamber pressure 1 p.s.i. followed by slow re-pressurisation.

2. Convulsions

Two convulsions due to oxygen toxicity are reported in our series. Both occurred at the unnessicarily pressure of 3 Atmospheres Absolute. It is now our practice to treat at 2.5 A.T.A. and no problems have occurred at this pressure.

3. Lung complications

Pulmonary effects from high oxygen tensions have not been evident but is has recently been decided to use 5 minute air breaks every 25 minutes on oxygen, particularly duirng prolonged therapy.
Deep breathing is encouraged, following removal of the patient to the normal air environment. This practice tends to prevent the onset of atelectasis.

4. Risk of Fire

Of all the possible problems, fire in an oxygen environment is the single item that would have tragic consequences. The late 1960's were beset by fires in space-craft, fires in research units and fires in clinical Hyperbaric Units. We were obsessional in following these precautions in eliminating all possible sources of ignition:-

1. No electrical circuits

2. No heating

3. No static

We therefore increased humidity and did not allow the patient to wear any synthetic clothing whatsoever. Pure cotton theatre garments were the usual apparel.

PATIENTS TREATED

1.	Ischaemic Limb Disease	44
2.	Specific Wound Infection	22
3.	Gas Gangrene	14
4.	Joint Bends	6
5.	Carbon Monoxide Poisoning	4
6.	Air Embolism	1
7.	Miscellaneous	9
		100

In our first one hundred cases we treated 44 ischaemic conditions, 22 specific wound infections, 14 cases of true gas gangrene, and 6 cases of joint bends, 4 cases of carbon monoxide poisoning with 1 of air embolism concluding the main series.

VASCULAR CONDITIONS

1.	Athero-sclerosis	15
2.	Vasospastic	12
3.	Post Operative Ischaemia	12
4.	Occlusive	5
		44

The high number of ischaemic limbs treated resulted from the activities and interests of the vascular surgeons at our hospital. The therapy was of dubious value in chronic ischaemic limb disease but often of diagnostic help in delineating an ischaemic boundary. Improved results were seen when combining the oxygen with oral $\propto$ blocking agents.

Surprisingly several patients with vasospastic disease involving the fingers did particularly well. Sudden dramatic relief of the spasm occurred either during or several hours after therapy.

A patient with Raynauds disease showed considerable improvement following one treatment session.

Wound Infections - Gas Gangrene

The 22 specific wound infection were mainly post operative; where clostridial welchii had been isolated or gas gangrene suspected. These progressed well and none went on to develop a toxic gas gangrene picture. It is of course impossible to ascertain whether oxygen any help since broad spectrum anti-biotic cover was administered in each patient.

Of all conditions treated none has been so satisfying, curative and life saving as the application of hyperbaric oxygen in gas gangrene. We totally agree with this statement obtained from a surgical colleague at the Royal Melbourne Hospital - “The treatment of clostridial gas gangrene with Hyperbaric Oxygen therapy has been a giant a step forward in the treatment of this disease as was penicillin in the treatment of pneumonia”.

All 14 patients in our series were toxic and exhibited clinical evidence of gas, crepitus, and wound discolouration. Seven had gangrene of a below knee amputation stump following surgery for peripheral vascular disease; 2 of these were diabetics. Self contamination of the stump from the rectum was the likely source of infection.

Six patients developed gas gangrene of the limbs following trauma; compound fractures of the leg after motor cycle accidents were a common cause. Gas gangrene of the abdominal wall occurred in two patients with colostomies.

All cases were treated at the following regime:-

1. Oxygen - at 2.5 ATA - 2 sessions daily, therapy continuing for up to 5 days.

2. Penicillin - approximately 24 Mega Units per day.

3. Surgical Debridement and Suture Removal - when necessary.

There were three deaths in the series, one followed severe abdominal trauma, another died with extensive secondary carcinoma and an 84 year old died five hours after surgical debridement.

It was interesting to observe that patients who were confused and apathetic before treatment became alert and co-operative in the high pressure oxygen environment.

Improvement in the system condition was often apparent following the first treatment.

There is no question that we totally agree with other workers in the field that Hyperbaric Oxygen in life and limb saving - an essential tool in the treatment of gas gangrene. Furthermore it may reduce the need for extensive mutilating surgery. In theory it converts a favourable environment for the anaerobes into an unfavourable one. Ischaemic tissues become oxygenated, toxin production is inhibited and penicillin activity is aided.

POSSIBLE INHIBITORY ACTIONS OF HYPERBARIC OXYGEN
↓
Cl. Welchii ⟶ beta Toxin ⟶ System Effects

COMPLICATIONS OF DIVING

An interesting group of patients treated were divers with joint pains. Four of the six were professional Abalone Divers. This group presented with severe shoulder pain associated with some restriction of movement. No other clinical signs were present.

Recompression therapy following Table 6A or 6B resulted in a full cure in all cases. We now feel it is desirable to intersperse 5 minute air breaks every 20 minutes, particularly when using the longer recompression table, ie. Table 6B.

Following treatment the patients are returned to the ward on oxygen. This practice tends to decrease the incidence of “niggles” in the next few days which is due to the nitrogen re-expanding the original bubble. We allow them home the following day, and they are told not to dive for at least one week - preferably two.

CARBON MONOXIDE POISONING

Only 4 cases of carbon monoxide poisoning have been treated. Our low figures compared with those from Sydney are likely to be due to the natural gas supply in Melbourne. Carbon monoxide however, is not a fashionable form of poisoning today.

All our cases were suicidal rather than accidental and all used a pipe from the car exhaust as a source of inhalation. Furthermore they had consumed prior to the attempt either sedatives, tranquillisers or alcohol. This common practice tends to confuse the overall picture. The experience gained was that Hyperbaric Oxygen was useful particularly in the later stages. It is useful for practical purpose to be aware of the half life of carbon monoxide in air and oxygen (Reference 1)

1. Breathing air - half life is 4 hours
2. Breathing 100% O2 at 1 ATA - 49 minutes
3. Breathing 100% O2 at 2.5 ATA - 9 minutes

Associated therapy involves the administration of steroids and diuretics for cerebral oedema and strict airway maintenance at all times. Psychiatric referral is invariably necessary.

In conclusion it appears that the indications for Hyperbaric Oxygen are clearly outlined:-

1. Gas Gangrene
2. Carbon monoxide poisoning
3. Radiotherapy of specific tumours
4. Air embolism
5. Decompression sickness
6. Surface infection, burns, ulcers
7. Selective ischaemic conditions

The Unit is available for use 24 hours per day and priority emergencies include air embolism, carbon monoxide poisoning, gas gangrene and joint Bends.

Experience has shown *Whom to Treat, How to Treat* and *When to Treat*.

The Unit is regarded as an important therapeutic facility which although not fully stressed on a day to day basis, is available when required. Since the completion of this paper one further case of gas gangrene has been treated. This patient received a gun shot wound of the abdomen and subsequently died following surgery of the bowel and abdominal wall. He remained intubated while in the chamber and was ventilated with a simple fluid logic ventilator. The ECG was monitored with praecordial leads connected to an external cardiac monitor through the special sockets present in the chamber door.

It is important to inflate the cuff of the endotracheal tube with water and not air, since pressurisation compresses the cuff and prevents a proper seal.

A further patient with gas gangrene of the abdominal wall following abdomino-perineal resection of the rectum has just completed five days of oxygen, antibiotics and surgical debridement, including the removal of left rectus muscle.

He appears to have made a satisfactory recovery and will not require further hyperbaric oxygen therapy.

Acknowledgments

I am deeply indebted to the following for their help and encouragement in patient management:

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And finally, Miss Prudence Brown, for her secretarial assistance, and the Nursing Staff in Ward 3 South, Prince Henry’s Hospital

References

1. Unsworth IP (1974) Acute Carbon Monoxide Poisoning, Anaesth. and Intensive Care, 4:329.

* * * * * * * *

Some people are abnormally sensitive to decompression sickness. One New Zealand diver is so liable that he must limit himself to 20 feet depth maximum.

Chest pain after a dive may indicate mediastinal emphysema or myocardial ischaemia.

Many divers are too buoyant to maintain a 10 foot or 20 foot decompression stop depth. Sport divers should avoid dives requiring decompression stops.

Cold gives little warning of the onset of Hypothermia. Abnormal behaviour (forgetfulness) may occur. 70% of the human body is within 2.5 cms of the surface. Activity increases heat loss. Danger period continues after the victim has been removed from the water. Heat loss occurs even in “warm” water. Severe but reversible hypothermia may produce a deathlike appearance and therapy be wrongly though useless.

In-water Oxygen therapy can be limited to 10 metres by so limiting the length of the gas supply hose.

* * * * * * * *

PROJECT STICKYBEAK
Dr. Douglas Walker

Provisional Report on the 1976 Australian Diving Deaths

Overview

There were twelve identified diving related fatalities in 1976. Of these two were in swimmers using fins, mask and snorkel, eight were scuba divers and one was using surface air supply (hookah)and there are insufficient details at present available to assign one case. Both the snorkel users were unused to its use and one of them was a poor swimmer, though he dissembled on this matter to others. One professional diver, using scuba, ordered his boat to keep one propellor turning in order to maintain position against an ebb tide while he investigated an underwater object. As soon as he entered the water he was drawn into the propellor tunnel and killed. The other scuba deaths occurred at the surface, often related to low air/ deteriorating water conditions/cold. While ignorance was gross in two cases, in the remainder this was not the cause as 4 had C-cards and one other had 30 years of diving experience. One victim suffered a fatal "heart attack" and another was said to be obese: the remainder were in good health. Buddies, where present, behaved creditably. The rapidity of the change through unconsciousness to death is worthy of comment. Once more the wearing of a functioning buoyancy vest can be seen to be a critical factor: two CO_2 type vests failed their wearers at the critical time. The hookah diver died through the cumulative errors of others and unsafe practices that were certain to produce a death at some stage. He was supplied with oxygen while working at 70 ft. This was possible because the gas supplier had the same thread on cylinders used for both gases and the colour-code was hidden by the method of storage. Naturally this user has corrected the faulty procedure but recurrence will remain a possibility until a different connection is required for different gases. This problem has been found in hospitals; faced with similar dangers, gas cylinder fittings were altered. In constructing the report the superiority of the information in cases where the Coroner spoke to the witnesses as well as viewed their depositions was evident, fewer points of interest remaining undocumented. The basic findings are given in Table 1.

Method

In most cases the details are from statementf taken soon after the incident by Police Officers skilled in guiding witnesses to make clear what has just occurred. They are concerned with excluding, as is the Coroner himself, any possibility of illegal or criminal aspects. It is no part of the task of those concerned to consider deeply whey that person died while another would have survived. Luckily in most cases background detail is included. In a few instances reports from those with knowledge of the events are received and these gain from the less formal setting out of the events. News cuttings are a vital part of the discovery of cases though they may not be entirely correct with all details on occasion. Additional cases may remain still undiscovered and readers are invited to send iformation they may possess concerning all types of diving incidents, not only concerning fatalities.

Case Notes

1. Snorkel (breath-hold) divers are represented by two fatalities, both overseas visitors to the Barrier Reer. Both were inexperienced in the use of fins, mask and snorkel. While one was said to be an adequate swimmer, the other was appprently not only a very poor one but had previously only use a snorkel while in shallow water. the warm, still, clear waters of the Reef can drown the unwary as easily as the colder, rougher waters of other areas. In neither case was help sufficiently near at the critical time.

Case BH 76/1

This unfortunate visitor, aged 28, was travelling on holiday with relatives on a yacht. The party decided to view the coral off one of the islands on which they had landed. The victim, described as an average swimmer, had previously only used a snorkel once. Early in this outing he was seen to be having some difficulty in co-ordinating breathing when underwater (through water entering the snorkel). This difficulty appeared to have been resolved before the party separated, the victim remaining in the shallow (3 ft) water 60 ft from the beach when the others entered deeper water. One member of the group became cold and returned to shore with the expectation that the victim was following him. However a headcount of the remaining swimmers disclosed the victim’s absence and the alarm was raised. About 10 minutes later a body was seen floating on the surface, minus mask and snorkel. Resuscitation attempts were unavailing.

Case BH 76/2

This death occurred during a normal commercial boat trip to an offshore reef. There was seemingly an assumption that all swimmers were fully competent to manage their own safety in the water, no actual proof of any experience being requested. There was not a small dinghy available to recover anyone getting into difficulties. Some remained aboard after the spearfishermen and the snorkelers had left. They happened to see the victim, aged 24, surface and wave his arm and shout for help. He was estimated to be about 150 m distant. Two scuba divers jumped into the water from the boat and swam to the spot but were initially unable to locate him. It was at least 6 minutes before he was found, minus mask and snorkel but still wearing his weight belt, in 10-12 m of water. The body could only be raised with difficulty because the weight belt had been put on in such a manner that it was difficult to release, though the victim had shown another person that the quick-release worked easily a few days previously. His claim that he had 4 months of experience with a snorkel was misleading, he having only used it when floating in shallow water as he was actually only able to swim a few strokes. The sea was calm and not an adverse factor. Resuscitation attempts were unsuccessful.

2. Scuba divers suffereed eight identified fatalities, equally divided between the ignorant and certificated. All appear to have experienced the criitical events when at the surface if one includes the unfortunate commercial diver who was destroyed by a propellor a few feet beneath the actual surface. It is not possible to state with certainty every event and factor surrounding fatal incidents but there is obviously a highly critical period in every dive when the diver is at the surface and death, whether following inhalation or from some other cause, can occur with extreme rapidity/ Reliable surface buoyancy is an obvious safety factor and the two instances of failure with CO_2 inflatable vests in this small series seem significant. As the buoyancy is most urgently required by a diver already in trouble it would be inappropriate to rely on any aid requiring oral inflation. The added security that buoyancy gives woould all ow time for the victim to think rationally and perhaps even drop his weight belt. The organised diving club outing's fatality was not the fault of either the buddy or the club and in other cases also the buddies did all possible to offer aid once it seemed to be necessary.

Case SC 76/1

Being an excellent athlete and swimmer, and having tried the use of snorkel and scuba (for 20 minutes) some 6 weeks previously, this healthy 18 year old accepted the opportunity offered by two others to again scuba dive. Their experience is unknown, as is also the source of the equipment used. The dive was to be off a rocky shelf that continued out to sea as a reef. It was a wave swept entry point such as experienced swimmers of all types would have totally avoided. One of the scuba divers and the victim entered the water but both were soon hit by a succession of unexpectedly large waves and tumbled about in the wash. The buddy felt the victim grab at him and observed on looking round that he looked dazed and no longer had the mouthpiece in his mouth. They were now being pounded on the rocks and only reached the shore again through the assistance of the third diver and the luck that one wave washed them sufficiently high on the rocks to make escape possible. It was stated that onlookers offered no help either at this desperate time or later with resuscitation attempts. There was possibly a little delay before effective resuscitation was initiated but it was continued efficiently when lifesavers and a rescue helicopter arrived, and continued in transit to a nearby hospital. Consciousness was never regained and death occurred three days later from the effects of cerebral anoxia and aspiration of water.

Case SC 76/2

About a year before this incident the victim had successfully completed a diving course and had been adjudged a good student. Since then he was thought to have made 8 dives. On this occasion he was with a friend. They proposed to swim to a nearby reef and then to scuba dive, but as he had a recently healed perforated eardrum he warned his companion that he might have to return to shore if he experienced any ear trouble. The other diver led the way as they started their surface swim out to the reef, and when half way there he looked back and saw his friend wave once, an action he took to indicate that he was aborting the dive. This was the last time the victim was seen alive, for when the leading diver reached the reef and stood up to check there was no sign of the victim. This made him a little alarmed so he returned to the beach. A short time later, while undecided as to what to do, he observed activity by the lifesavers who were attempting to resuscitate a person a snorkel diver had found lying on the seabed in 4 m (13 ft) of water about 70 m off the beach. Weight belt and tank were still on the body. Neither diver wore a buoyancy aid and the scuba air was turned off, it being their intention only to start using scuba when the dive commenced at the reef. The sea was calm. Autopsy revealed drowning changes and no disease changes in this 36 year old man. It is easy to suppose that survival would have been assured if a buoyancy vest had been worn and the air had been turned on.

Case SC 76/3

This experienced part-time professional diver forgot the powerful suction effect of a revolving propellor, with fatal results 15 seconds after entering the water. He was aged 40, had a basic C-card qualification and was respected as being conscientious in his work. This day’s task was the finding, and later recovery, of a large and very valuable anchor that had been lost in a harbour tideway, a type of search and recovery task with which he had previous experience. The method he chose was to drag a large metal bar between two steel hawsers which led over the sides of a powerful tug. They were steaming into an ebb tide when an underwater obstruction was encountered that required checking. The diver ordered the tug captain to maintain position against the water flow by use of one propellor at low speed. The propellers were in short tunnels a few feet beneath the surface.

His plan was to follow one of the hawsers till reaching the object that he been fouled. He was warned about the propeller’s turning and apparently said that if this caused problems he would try a different method the next time. This was the first time he had been known to enter the water in such circumstances. He jumped overboard and swam back to the wire hawser before submerging. A few seconds later a thump was heard and blood stains appeared in the water. He had apparently been irresistibly sucked into the propellor tunnel and killed.

Case SC 76/4

The victim was a 20 year old diver with two years experience, his buddy one year. Both had taken courses and obtained C-card certification, in different States, about a year previous to this dive. As the buddy had only dived 4-5 times in total he accepted that his friend had more experience and would be likely to use less air on the dive.

For this reason the friend exchanged his hired tank for his buddy's equipment. There were no contents gauges on the tanks but both had been recently filled. The buddy diver alone had a buoyancy vest, this being purchased the day before the fatal outing. At the dive site, an off-shore reef connected to the beach by a jetty, they debated the suitability of the sea conditions but the victim thought that despite the cold windy conditions and a choppy sea it was possible to dive successfully. He was not experienced in the local conditions and obtained no local advice, and being motivated to some degree by the $13 he had outlaid to hire the tank and regulator was unwilling to accept a no-dive decision.

They swam out underwater after a short delay to correct the buddy's weighting, keeping close together. After a period at the reef they decided to return to the jetty steps, again underwater. However the buddy soon became low on air, pulled his reserve, surfacing after signalling his intention. The two then decided to surface swim the remaining distance together, the victim to be the leader. The buddy inflatedhis vest and as a natural matter of convenience swam on his back as he followed, thus inevitably losing sight of the other. He became aware of shouts from people on the jetty but could not discern what was being said, being distracted in part by stomach and leg cramps, exhaustion and increasing waves. Witnesses on the jetty saw the victim wave as if for help and a diving instructor, who was just concluding a lesson with two pupils at the jetty steps, responded by dropping his tank (to increase his surface swimming speed) and going to offer assistance. However the victim was no longer visible on the surface when he reached the spot so he returned to don his scuba tank and then started an underwater search. The victim was found lying on the seabed in about 5 m (16 ft) of water. The weight belt and tank were easily released and the body recovered. The period of submergence was over 15 minutes so resuscitation attempts failed. The equipment was later recovered and tested. Apart from being empty of air, there was no adverse comment on the equipment.

Case SC 76/5

Aged 24 and armed with one year's diving experience and a C-card obtained after a course, this diver was on a boat dive with fellow club members. The sea and weather conditions were good, underwater visibility excellent. All the divers were certificated and were checked as to their equipment and buddy pairing before being allowed to enter the water. As the boat owner accurately summed it up, "I checked because I am the one who has to fish them out later". He remained in the boat and was a very efficient "surface cover" as events showed. The victim and buddy kept close together during descent down the sloping sea floor and eventually reached 30 m (100 ft), here meeting by chance a pair who had entered the water before them. One of this pair realised that he was low on air so they made an orderly ascent. Suddenly the buddy realised that she was alone, her companion no longer visible. She therefore returned to the anchor line, expecting to find the buddy there or already surfaced and waiting at the boat. She ascended alone to find that the line had been buoyed, the boat was gone and that the other pair of divers at the float had not seen the missing diver. The man left in the boat reported that he had seen a diver surface about 150 m away and call several times for help, so he had buoyed the anchor and proceeded immediately to the spot. Unfortunately no trace of any diver could be seen so he returned and collected all the dive party, checked that one was indeed missing, and returned to institute an underwater search in the area of sighting. Other divers joined in and ultimately the body was discovered in 12 m (40 ft) of water in the expected area. The weight belt was still in position and the CO_2 type vest was not inflated. As more than one hour had elapsed there was no point in resuscitation attempts. Subsequent investigation showed that the tank still contained 900 psi of air and that all the quick-releases functioned correctly. The victim had previously spoken about free-flow trouble with the regulator to a friend but had not mentioned this at the dive shop when obtaining air for this dive, so it was presumably an inconstant problem. Testing showed that there was a mild problem with water entering the mouthpiece but this was not to a degree likely to trouble a trained diver. However the lifejacket's CO_2 cylinder spontaneously fired after the vest had been washed and put aside for later examination by the police. It was thought likely that the firing pin had dented but not fully pierced the seal during the incident and the perforation became completed as a result of later handling.

There was no known reason for the victim to make a sudden ascent without warning the buddy first, for visibility was good and his air supply was still adequate. Possibly a shark was seen or a misfunction of the demand valve occurred. As the victim shouted several times after reaching the surface and the autopsy showed no signs of pulmonary barotrauma, only drowning changes being described, air embolism cannot be readily suggested. It is possible that after a successful 30 m (100 ft) ascent there was some surface buoyancy inadequacy, the vest failed to inflate and water was inhaled before thought could be given to releasing the weight belt.

Case SC 76/6

The initiating factor in the sequence of events that led to this fatality was the loss of a facemask, followed shortly by a unplanned water entry. The diver, aged 55, had 30 years experience with scuba and was standing on a reef with his buddy after a dive. They both raised their masks while discussing whether to return to shore along a jetty or by swimming. The buddy was tired and getting low on air, underwater visibility was poor, but it was decided to swim. At this time a small wave broke over the reef and tumbled the victim off his feet. He surfaced a short distance away, minus his mask. After helping him back onto the reef the buddy attempted to recover the mask but the turbulent bubbling water off the reef made this impossible. He surfaced from his search to see the victim floundering on the reef so attempted to reach him again, and the next thing he remembers is seeing the victim 10 m away from him in the water. He inflated his own buoyancy vest and managed to rejoin his friend. He told him to drop his weight belt but this was not done and neither did the victim follow advice to inflate his vest, though he was seen to attempt to manipulate the vest's mouthpiece. He was still retaining the regulator in his mouth but seemed to be in some undefinable trouble. The buddy, despite trouble with cold hands, managed to drop the victim's weight belt but was unable to manipulate the release of his own with one hand. The victim was passive at this time and the buddy started to tow him to shore but had to let go for a short time to use both hands to drop his own weight belt. During this period the victim drifted 10 m away again and increasing waves prevented contact being re-established. A motor boat chanced by, saw the buddy's wave for help and picked him up. He was exhausted and completely out of air by this time. The boat was then directed to the victim, who was unconscious but retained the demand valve mouthpiece in his mouth. It is not certain whether he was still breathing. Resuscitation was started in the boat and continued on the beach but was unavailing.

Investigation later showed that the victim's tank still contained 1,100 psi air but that the inflatable vest had an "expired" CO_2 cartridge and the mouthpiece was not functioning. The vest was in poor condition and was described as being useless. The autopsy showed drowning as the cause of death. The victim showed no real signs of consciousness after being seen to attempt to use his vest. The buddy had two years (45 sea dives) experience but felt remorse that he had not been more physically fit so as to do more for his companion. The record shows that in fact his actions were highly commendable despite the unfortunate outcome.

Case SC 76/7

Three friends went scuba diving together off a wharf jetty. The water was clear but cold, with depth about 12-13.5 m (40-45 ft). They swam underwater in visual contact about 5 m (16 ft) apart and surfaced when one became low on air. They all surfaced normally and started to make their independent ways back to the jetty. There was by now a 0.6 m (2 ft) “slop” to the water.

A witness on the wharf heard what he described as “a gurgling yell” and looked down to see a diver on the surface paddling feebly with his hands, his face held up out of the water. He was seen to let his head fall forward and his face submerge. Another witness saw the victim estimated as being 9 m (30 ft) from the jetty, on the surface attempting to release his tank: his mask was half full of water and water was going into his mouth. The alarm was raised immediately. The two other divers, who were approaching the steps on the other side of the jetty to that chosen by the victim, were told their friend was in trouble. One of them said that he was too exhausted to re-enter the water because of the rigours of the return swim, but the other discarded his tank and swam to offer help. The victim was now about 4.5 m (15 ft) from the jetty, unconscious and without tank and weight belt. He was brought out of the water and resuscitation attempted, but without success. It seems probable that death occurred before removal from the water. Check revealed that very little air remained in the tank. None of this trio had any buoyancy aid. Although the victim was accounted to be a fairly experienced diver, in fact, his 2 years of diving had been largely with hookah apparatus, and the statement that he was in good health was qualified by the doctor performing the autopsy who described him as obese. He was only 32 so this doctor was surprised that such a sudden death had occurred and suspected some cerebral haemorrhage and therefore limited his examination to the cranial cavity. As no such disease was found, drowning was diagnosed.

Case SC 76/8

This 45 year old man was diving for crayfish from a boat on this, his first open water dive. It is said that he had practiced diving a number of times on inland waters but his skill is unknown and neither is it known whether he received any instruction. The party consisted of one diver using a snorkel and three using scuba. The three scuba divers completed their dive and swam back to their boat, on the surface, the victim being the last in line. After boarding the boat they observed him floating face down on the surface. Although not really worried by this they decided to start the engine and go pick him up as he was quietly drifting away from them. After some delay occasioned by difficulty in raising the anchor they reached him. He was found to be unconscious so was taken into the boat and both EAR and ECC started, unfortunately without success. Autopsy revealed that a myocardial infarction, due to vascular disease, had occurred. No evidence about the victim’s previous health was presented to the coroner.

3. Hose air supply diving (also called hookah or surface air supply) provided one tragic but very significant case. Those immediately involved were the unfortunate victims of a series of decisions made by others not present, in times long past, that had set up an unrecognised fail-fail situation. they merely made the final mistakes that completed the scenario.

Case H 76/1

This experienced and well trained diver was working with others from a regular dive boat attending to moorings. Only one diver was underwater at any time. The air was supplied from a double bank of 150 cu ft cylinders, two rows of five, kept protected (i.e. hidden) at the stern by a wooden cover. There were two lines from this bank, one being coiled on the deck and the other attached to the diver’s harness for present use. A mouth-held demand valve was being used in connection with this hose supply and the diver wore a mask covering eyes and nose only. The water depth was 21 m (70 ft) and a total dive time of 30 minutes was allotted to each diver in turn, this allowing a generous safety margin for hard work component. The dive pattern was descent, attach lifting cables, ascend while lifting in progress and descent again for next attaching task till time was expired. Only one diver was underwater at any time. The man whose dive preceded that of the victim noticed that the gauge indicated that the in-use cylinder was low so changed the attachment to a full cylinder. This change-over was not the specific responsibility of any designated person apparently. The victim entered the water and dived to the same pattern as all the others, making two surface excursions as required by the above plan. No variation in his actions from perfect normality was noted. When he failed to respond to even a second signal, and the absence of ascending bubbles was noted, the standby diver was immediately sent down to investigate. He found the victim lying on the harbour bottom minus his mouthpiece and unconscious. He was raised as rapidly as possible and resuscitation started using an Oxy-viva and ECC on the dive-boat. Although there were no definite signs of life attempts continued and the set's oxygen supply became exhausted so it became necessary to change to the large cylinder of oxygen that was aboard for just such an eventuality. It was now discovered that the oxygen cylinder was already coupled up to a hose, the diver's supply hose. Though resuscitation was continued during the trip to shore and onwards to a major hospital, it was unavailing.

Autopsy showed that death resulted from drowning, this following unconsciousness from breathing oxygen during work at 21 m (70 ft) depth.

The most immediate error in the chain of events was the connection of the incorrect gas supply to the diver's equipment. This occurred easily because only the cylinder valve was visible, the colour coded shoulder being hidden behind protective flooring. The only precaution taken against this type of mistake was the general knowledge among divers who were likely to dive from the boat that the oxygen bottle was always the bottom left one in the rack of the ten 150 cu ft cylinders. Naturally the reliance on traditional practices was immediately changed to a fail-safe method in that the oxygen cylinder was separated from the air cylinders from this time. Nevertheless the events could never have occurred had it not been possible to connect up the hose incorrectly. Hospital anaesthetic fatalities have amply demonstrated the imperative necessity for different thread sizes for each type of gas if machines are not to be wrongly connected up on occasions. Nitrogen and helium have elsewhere, it is believed, been supplied to divers with similarly fatal outcome. There are other (fire) dangers too if oxygen under pressure passes through incorrect fittings. Attention could well be given to this matter before a similar misadventure occurs in some other diving group. It is to be noted that this tragedy illustrated that it is unwise to assume that any procedure is safe merely because no accident has yet occurred. Only frequent positive reassessment of current diving practices will keep unsafe practices at bay.

Discussion

The primary lesson one can draw from these eleven case histories is that one can never afford to hold the sea in disrespect. It is necessary to be able to swim and to master a snorket, a piece of equipment too little respected, even for calm water safety. The frequency of the fatal pattern of events devloping in divers at the surface illustrates that one is not home and dry until safely out of the water and the dive plan must take account of this fact. The surface layer is the killing ground for those whose training and equipment are not up to the demands of the occasion, the rapidity with which death can occur making the prevention of the aspiration/unconsciousness/death progression preferable to an over optimistic belief in the efficiacy of resuscitative measures in such casualties. Though reliable buoyancy vests were of value to several of the survivors, none of the victims had such aid. The failure to function of the vests of the two victims who had them confirm the belief of many that CO2 inflatable vests are liable to failure at the crisis time, which at the very lease musst be bad for the user's morale. Both cold water and worsening sea conditions are significantly noted by survivors and lack of bhoyancy, with little or no remaining air, aggravate the risk of exhaustion and compounds the problem of making a safe landfall.

In one case the fatality was due to a “heart attack” in a diver separated from his friends. This raises the question of fitness to dive. It is unfortunate that the victim’s medical history is unavailable but the experience gained from the examination of Australian airline pilots over a ten year period has been that there is a poor predictive score from the routine examination and resting ECG when checked against later events. Of the twenty pilots in the study who suffered conronary thrombosis only one was "predicted" while three infacrcts occurred unnoticed between routine ECG checks. Few of the pilots who were disqualified from flying on the basis of ECG changes were known to suffer a later coronary thrombosis. Of course no of this group had admitted symptoms. One other victim was said to be obese, with the implication of reduced fitness. Both these cases also involved significant factors additional to the health problems.

A better assessment of sea conditions, an adequate reserve of air in the tank for the return from the dive and a reliable buoyancy reserve are basic requirements for even the “certificated and experienced” who wish to reduce the odds against them. It is advisable to fit a submersible contents gauge, and be guided by it. Look before you leap into the water and as always, THINK.

Notes to Correspondents and Authors

Please type all correspondence and be certain to give your name and address even though they may not be for publication. Authors are requested to be considerate of the limited facilities for the redrawing of tables, graphs or illustrations and should provide same in a presentation suitable for photo-reproduction direct. Books, journals, notices of Symposia, etc will be given consideration for notice in this journal.

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DISCLAIMER

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TABLE 1

Case	Information Source	Age	Skill	Vest	Buddy	Air status	Brief notes:
BH 1/76	Inquest	26	nil	no	no	-	alone, 3ft deep, calm sea
BH 2/76	Depositions Report	24	slight	no	no	-	poor swimmer, calm sea, 44ft deep
SC 1/76	Depositions	45	slight	no	sepn	???	1st open water dive: CT.
SC 2/76	Depositions	36	C-card 1 year	no	sepn	off	surface, calm sea
SC 3/76	Inquest	40	C-card	no	no	full	professional diver killed by propellot
SC 4/76	Depositions Report	20	C-card	no	sepn	low	COLD, rough; waved for help, surface buddy vest
SC 5/76	Inquest	21	C-card	FAIL	sepn	satis	surfaced from 100ft; calls for help
SC 6/76	Depositions	55	30 yrs	FAIL	YES	satis	COLD; lost mask; washed off reef; rough water
SC 7/76	Depositions	32	slight (hookah)	no	sepn	empty	COLD; rough; dropped wts, tank; Surface
SC 8/76	Inquest	18	nil	no	YES	full	rough sea entry off rocks.
H 1/76	Inquest	23	trained	no	no	**	supplied oxygen at 70 ft

<u>KEY:</u>

Depositions = statements of witness as to police at incident time
Inquest = witnesses with statements before the Coroner
Report = direct “Stickybeak” report by a witness
Buddy YES = Buddy present and active help all critical times
Buddy sep. = Buddy separated at critical time of the incident
Buddy no = dived or swam alone on the incident dive
COLD = witness assessment that this a significant factor

THE NEAR-DROWNED AFTER A SUCCESSFUL RESCUE

John Pearn
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When an individual child is taken apparently dead, from the water the first concern is the re-establishment of heart beat if this is absent, and of respiration. In a major epidemiological study of fresh water drowning accidents (The Brisbane Drowning Study) we have been able to look in detail at subsequent events in survivors. Detailed data is available for fresh water cases only, but we have considerable anecdotal and case history experience with salt water cases as well.

SURVIVAL RATES

Of all unsupervised children who lose consciousness in fresh water, almost exactly 50 percent will survive. The survival rate in such circumstances is higher in swimming pool immersion accidents, and lower in creeks and rivers where the extraction time tends obviously to be longer. The data for surf rescues is approximately 75 percent survival. Whether this difference is due to the altered pathophysiology of drowning in the two types of immersion medium is doubtful; it is more likely that a child in difficulties in the surf is extracted more quickly than a child overlooked and drowning in a home swimming pool, and survival rates probably are measuring the immersion time (and by inference, the degree of anoxia).

Survival rates from Royal Navy data are low, but the complicating influence of icy water conditions makes comparisons very difficult to interpret. One has evidence from The Brisbane Drowning Study that colder water (but not freezing) offers protection from cardiac and cerebral anoxia up to a point, but there comes a stage as the water cools further when any advantage is lost because of complicating cardiac effects due directly to hypothermia.

TIME TO FIRST GASP

A common question that arises for all involved in rescue and first aid work is "how long should one press on with resuscitation if no vital signs return?" We have now personally interviewed the parents, resuscitators and medical officers involved in over 70 extractions of an apparently dead child from the water. In those cases who survived (56 in our series), the median time until the first respiratory gasp was 5 minutes, with a range of 15 seconds to 60 minutes. In all but two cases of survivors, respiration was established within 25 minutes after extraction from the water, irrespective of the skill of resuscitation, In most cases the response was very quick. One child who did not respond until 25 minutes after rescue, had a stormy several days in intensive care, but has recovered completely with a normal IQ measured by formal psychometry. In two cases (4 percent) there was no gasp until between 30 to 60 minutes after rescue, and both children have suffered mental retardation and physical damage (spastic quadriplegia). At water temperatures encountered in tropical and subtropical Australia, I personally feel that there is no point in continuing resuscitation after 60 minutes. A note of caution is needed here, as one has to be sure that one is not dealing simply with a frozen or near-frozen victim, rather than a dead one. It is well known from Naval experience in the Northern Hemisphere that vital signs may not return for after 1 hour if the individual is very cold, but prognosis may stll be acceptable.

WHAT HAPPENS DURING RESUSCITATION

Our experience with fresh water accidents is that about half the would-be resuscitators panic and are ineffective in resuscitation. One mother, on seeing her toddler son on the bottom of the family pool, ran inside hysterically and rang her husband, and only subsequently tried to extract him from the water - a fatal case. About 10 percent of cases were resuscitated by other children; if one is diving or swimming with a child over the age of 8 years, he should be able to give mouth-to-mouth resuscitation and should be trained to this end - “out of the mouths of babes ... “may come succour. Edmonds’ excellent teaching on buddies, in the general context of water safety, is appropriate in this context, and the concept should be extended to older children as well .

Our data from The Brisbane Drowning Study shows that in 50 percent of the cases of survivors, the trained resuscitator just happened to be present, but in only 10 percent of fatal cases. I feel this cannot be just coincidence. This offers tangible proof that trained resuscitation does indeed turn probable fatalities into survivors.

In one-third of the survivors, the first signs of body movement in the hitherto apparently dead child was a chest and abdominal heave leading to vomiting. In the other cases respiratory gasps were the first signs. It is important to be aware of the high likelihood of a copious vomitus (consisting of swallowed water, detritus, and less connnonly food), so that the airway can be maintained. This vomit, is in my experience, a very good prognostic sign. In 90 percent of cases consciousness returns within 10 minutes of the establishment of respiration.

Unfortunately, there is no acceptable data on cardiac action, or on the presence or quality of the pulse during real life resuscitation experiences involving fresh water immersions. From our experience, using anecdotal and case history material, we know of no instance where a child was not resuscitated if a demonstrable pulse was noted in the immediate post-extraction phase. Most resuscitators say, in retrospect, that they were not able to feel a pulse at the time of extraction or rescue.

AFTER BREATHING RESTARTS

In most cases, if gasping starts, normal respiration is fully established within 2 to 3 hours, and often within 30 minutes. In 3 children in our series of 56 survivors, however, respiration subsequently stopped a second time; in one case, this happened several hours after the successful initial resuscitation when the child was fully conscious, and in fact had not been admitted to hospital at that stage. This phenomenon of “secondary drowning” is well recognised in both fresh water and salt water cases, and is probably due to aveolar collapse and surfactant loss due to the lungs containing large amounts of water. I feel that all resuscitated cases must be admitted to hospital for observation for 24 hours at least. In spite of the voluminous literature on electrolyte and haematological changes after salt and fresh water drowninqs and near-drownings, in no case did we encounter any evidence of hyperkalaemia or haemolysis in survivors.

Some degree of cerebral irritability is common in the first 12 to 18 hours after resuscitation. In approximately 10 percent of cases this is quite dramatic, and produces spasms which are provoked by non-specific stimuli. High pitched cerebral crying or screaming and Biot breathing may also be observed. In my experience this rather worrying pattern in the first few hours after rescue is in no way a grave prognostic sign.

MENTAL FUNCTION IN THE SUCCESSFULLY RESUSCITATED

We have undertaken formal psychometric studies in 33 children who were over the age of 3 years, and who survived. The median IQ of survivors is 110, which is at least 6 points higher than that for the general population. To explain this surprising (but heartening) finding, it seems inescapable that survivors are being selected in some way. Perhaps it is the brighter more adventurous child who gets into difficulties in the first place. It may be that more intelligent parents are better resuscitators, and their children are more likely to be more intelligent on that account. Whatever is the reason, the outlook for mental function is very good indeed, and one should certainly press on with resuscitation efforts with a full knowledge that if one is successful, in 95% of cases the child will have a normal overall IQ. In one of our cases (a domestic bathtub immersion) the child was resuscitated after 40 minutes, but is grossly brain damaged with amentia. I have also treated one case where the measured IQ in this survivor (first gasp at 60 minutes after extraction) has increased from almost immeasurably low levels at one week, to 97 several months later, but this is unusual.

Unfortunately, it may well be that the prognosis is less favourable for adults who are resuscitated from similar accidents, but there is no published series yet to give accurate data here. We also do not know whether salt water immersion victims are different in this context. My impression is that it may well be that there is less likelihood of brain damage after a successful salt water rescue and resuscitation.

We have encountered no emotional after-effects whatsoever in long term follow-up studies of these near-drowned children. 50 of 54 personally examined children in this series have total amnesia for the immersion event. Only 3 of these showed any fear of water subsequently, and an almost universal response by parents was that the child was in no way more cautious of water hazards after his ordeal.

PHYSICAL SEQUELAE

All but one child of the 56 survivors (a consecutive unselected series) were completely unchanged physically after the near-drowning. I personally examined 51 of the children neurologically and there is no evidence of any hard neurological signs in all but one of these. No child suffered recurrent respiratory problems or middle ear difficulties subsequently. Pulmonary interstitial fibrosis has been reported in the literature in at least one case The one child with neurological side effects had gross spastic quadriplegia which has remained as a permanent handicap after the accident. This is the one child who also has amentia, and he manifests extensor spasms triggered by non-specific stimulation. This is not to say that other side effects do not occur, but they are rare. The known sequelae after near-drowning with hypoxic brain damage include dysarthria, extra-pyramidal features,upper motor neurone signs, and peripheral neuromuscular complications. X-ray changes in the chest are almost inevitable after rescue. Perihilar pulmonary oedema, and generalised pulmonary oedema are the most commonly observed findings. It is generally considered that these changes are probably secondary to hypoxic lung injury and usually clear within 3 to 5 days. No lung changes either clinically or radiologically are usually apparent within 5 days after a successful rescue.

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ALLERGIC REACTIONS TO MASK SKIRTS, REGULATOR MOUTHPIECES, AND SNORKEL MOUTHPIECES

A preliminary report by John E. Alexander MD, Falls Church, Virginia*

SCOPE OF PROBLEM

A severe intra-oral irritation, vesiculation, and generalized inflammation which I attributed to a systemic reaction first called to my attention the clinical entity of allergic reactions to diving equipment. Seven years later I published a small "blurb" in Skin Diver's Driftwood Column and the response made me aware that this problem was far from unique with me. More than fifty letters, some agonizing, were received and, during the past year, I have received direct information on many more cases. One scuba instructor, a very fine observer, stated that about 25% of her students showed some reaction to regulator mouthpiece. Allergic reactions caused by fins and/or fin straps have also been reported to me.

ETIOLOGY

The actual chemical constituents of the rubber used in the manufacture of mask skirts or mouthpieces are unknown. However, one of the most common causes of contact dermatitis in surgeons who wear rubber gloves is the antioxidant or accelerator mercaptobenzothiazole. This may be a factor in the condition I am describing and its elimination would probably be helpful. There could be other etiological agents and constant pressure could be an additional factor. It must be borne in mind that frequent minor insults to body tissue, while not producing symptoms, can be cumulative enough to cause complete sensitisation. For this reason, a diver may use a mask, snorkel, or regulator mouthpiece many times without severe reaction until this endpoint is reached. Then there occurs a full-blown contact dermatitis of the face or a severe intra-oral inflammatory process.

TYPICAL CASES

Mask In the past, irritation from a facemask has been known as "mask burn" and was frequently passed off as a necessary annoyance of scuba diving. Characteristically, this varied from a red imprint of the mask skirt contact with the face all the way to a severe disabling erythematous reaction, with vesiculation, severe pain, weeping, and crusting of the skin. I saw one case so serious that I suggested hospitalization under the care of a dermatologist. When a severe reaction occurs, it takes weeks before it subsides and a mask can be worn again.

Oral Reaction to Mouthpiece Minor insults can occur in the mouth without disabling symptoms for long periods of time. However, when a reaction occurs, it looks thus: a mild burning sensation of the mouth when hot drinks, fruit juices, or heavily spiced liquids are taken progresses to inflammation, redness, vesiculation of the oral mucosa, gingiva, and tongue; and I have seen it extend into the pharynx. The pain is severe! This clinical entity could be linked to a cross between a very severe aphthous stomatitus and trench mouth. (The differential diagnosis could be made by history and microbiological studies). I have observed cases where eating and talking had to be curtailed.

TREATMENT

The treatment, of course, is to first remove the irritant - stop diving temporarily! If the reaction is severe, consult your physician and show him this article. Symptomatic relief for serious intra-oral reaction has been obtained by using a mouthwash consisting of equal parts of Elixir Benadryl and Milk of Magnesia. This necessitates a medical prescription. Severe reactions on the skin of the face require the services of a skilled dermatologist.

Future treatment requires the use of a hypoallergenic mask and mouthpiece. This statement requires a recommendation. While there may be others, I have been working with Dick Bonin, President of SCUBAPRO, who has been aware of this problem and has wanted to help, not to make money but to assist in making diving more comfortable and pleasant. We had talked about making these products from silicone rubber, since in my specialty I have seen this material (Dow Corning Medical Grade Silicone) used in thousands of cases and have never yet encountered an allergic reaction. (This is part of my speciality of Plastic Surgery). I had also talked with the president of a scuba equipment manufacturing firm about eliminating mercaptobenzothiazole and discovered that he already had in his inventory a gum-rubber mouthpiece that did not contain this clinical irritant. It was tried and found to be hypoallergenic and I recommend it. Other masks made of silicone rubber are available and I feel they are hypoallergenic and I recommend them.

In conclusion, I wish to observe that any individual with any kind of allergic history, who is diving or planning to dive should consider the purchase of silicone or gum rubber mouthpieces and masks.

The author of this article is a Plastic Surgeon with 13 years diving experience, NAUI Certified, Diving Medicine, and a member of UMS since 1968.

* * * * * * * *

The article by Dr John Alexander, which first appeared in PRESSURE (Feb 1976) is reproduced by permission of the author. It is one more reminder that nothing is entirely neutral and innocuous under all conditions. Divers are reminded of this fact whenever they hear the words 'Inert Gas' applied to Nitrogen, Helium, etc.

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SAFE EVACUATION OF DIVERS UNDER PRESSURE Continued from page 48

Immediate response to local emergency:

Is the problem immediate?
How much time is available to make decision on evacuation?
What men are available to assist?
What power is available to assist?
Does the weather forecast suggest that a compression chamber can be safely launched into the sea?

Evacuation

Evacuation under pressure must be classed as the ultimate emergency, the emphasis being placed on "Prevention", "Continuing Awareness" and "Immediate Response".

This paper is circulated for consultation. The increased availability of diving ships in the North Sea may well help to improve the chances of safe evacuation under pressure. In turn this may lead to the need for standardised mating techniques in the long term. Constructive comments, proposals and recommendations will be very much appreciated. Address for correspondence: Commander SA Warner, Chief Inspector of Diving; Department of Energy, Petroleum Engineering Division, Thames House South; Millbank; London SWIP 4QJ; UK.

SAFE EVACUATION OF DIVERS UNDER PRESSURE (Offshore operations local Emergencies)

Commander SA Warner

Legislation

The offshore Installations (Diving Operations) Regulations 1974 Schedule 1 para 4 (g).
The Merchant Shipping (Diving Operations) Regulations 1975 Schedule 1 para 4 (g).
The Submarine Pipelines (Diving Operations) Regulations 1976 Schedule 1 para 4 (g).

Introduction

History has shown that under rare, but often traumatic conditions, it is necessary to evacuate an offshore installation, a barge, structure, vessel or a ship. (During the period 1955-1974 there were 70 major mobile rig mishaps and 20 minor mobile rig mishaps worldwide).

Evacuation can be necessitated by fire, collision, extreme weather, blow-out, etc. It is essential that the possibility of such emergency be considered first with a view to minimising the risk, and second to develop a planned response to an emergency, should it arise. This paper is an appraisal of the possible emergency situations, and outlines some of the essential features which operators should consider.

THE RISKS

Fire

Fire can occur on board an installation or vessel at any time, therefore it is necessary to have the strictest fire precautions in operation at all times. Due to the particular risk to diving installations, consideration must be given to siting them with all essential equipment inside a deluge area, or in close proximity to fire hydrants. Consideration should also be given to the possible use of fire protection screens. In ships, consideration should be given to the siting of diving equipment in areas not generally recognised as high fire risk areas.

Collision

Even with sophisticated navigational aids, collisions at sea do occur. Strict adherence to the rules for prevention of collision are especially necessary and efficient patrolling of restricted areas is similarly essential. Special care is needed with ships coming alongside as part of their business when divers are under pressure.

Weather

It is well known that North Sea weather conditions are among the worst, most extreme in the world, and there is a very short weather warning. However, given a warning of impending bad weather, consideration should be given to delaying the commencement of saturation or long planned decompression dives. Good communication between diving supervisor and vessel or installation management is essential. Consideration should also be given to producing a procedure whereby decompression from saturation commences if the weather deteriorates to a given state and immediate meteorological forecast shows that rapid improvement is unlikely (ie. Sea State 7, Beaufort wind force 8, or when the vessel is forced to lay to weather anchors or head for a sheltered haven).

Blowout

In the event of a major blowout at the seabed it is possible that the surrounding area will become so aerated that normally buoyant hardware could sink. Further, although a blowout presents a very high fire risk, providing a fire prevention system is maintained, a normal surfacing safely schedule may be possible.

Although blowout can represent a major risk to diving operations, throughout the history of offshore oil exploration and exploitation there has only been one occasion when it has been necessary to evacuate divers, either operating or under pressure. There have been at least 50 occasions when an installation or vessel has had to be evacuated. However a serious blowout represents an extremely hazardous situation.

Good communications between drilling operatives and the diving supervisors to ensure that diving is not undertaken during operations involving high risk is essential. (Such things as: ballasting of semi-submersibles, rig work-overs, drilling operations when entering known or suspected hydrocarbon zones, etc. should form the basis of communication between the drilling operatives and the diving supervisors).

Evacuation Techniques

It cannot be stated too often that a response to an emergency situation will never be as effective as prevention of the situation. However, an emergency situation could always occur and emergency procedures and possibly special hardware may save lives. The undoubted fact that all disaster situations cannot be catered for should not delay actions to cater for an appreciable fraction of the eventualities.

Several possible methods of evacuation under pressure are under consideration and a few general conclusions should be considered.

Evacuation by Diving Bell

It may be possible to evacuate 3 or perhaps 4 divers under pressure in a diving bell by transferring the bell to another vessel.

If a rescue vessel with the necessary lifting gear, with deck chambers and with compatible bell-mating systems, can be brought alongside, the transfer could be made relatively quickly employing the transfer under pressure technique.

In the absence of such a vessel it may be possible to float the bell away from the installation or vessel at risk.

For this method, the buoyancy and stability of the bell in the water, as well as the autonomous life support and temperature maintenance systems, are essential as well as means of recovery from the sea.

The technique of launching the bell into the sea and the actual position of entry, must be considered. (It is no good just slipping a bell into a moon pool, neither is it acceptable for the bell to be slipped from any height.)

The actual freeboard from the diving complex to the surface interface must be considered. For example some barges have only a few feet freeboard whereas a platform may well have over 100 feet.

Evacuation by One/Man Chambers

Under limited circumstances the transfer of men might be made in individual chambers. One might consider the possibility of a store of one/man chambers equal to the number of divers under pressure, being kept available so that with, the appropriate life support, these individual chambers could be evacuated together with other personnel.

A limited number of divers could possibly be transferred using the medical evacuation chamber currently being fabricated.

Evacuation by Purpose-Built Safety Chamber

It is clear that a major limitation of all rescue methods is the time required to operate the rescue system and the number of people involved in the operation.

Since emergency situations will frequently arise rapidly, the means of rescue must be capable of rapid deployment by the minimum number of people. This basic requirement has given rise to the concept of specially designed chambers with rapidly disconnected attachment to the main complex, the chamber accommodating the whole team of divers.

Consideration of sea state, launching technique, buoyancy, stability, life support, heating and means of recovery apply as for the diving bell.

The stability in a seaway of a purpose-built rescue chamber might possibly be achieved by the planned application of external buoyant insulation.

A "float-off" technique for such a chamber should be considered.

General Considerations

It is not intended here to develop the engineering concepts nor discuss the merits of the various evacuation techniques. Two overall points should, however, first be understood.

(a) There is evidence that increased attention to preventative measures may be more cost effective than special evacuation systems. This topic requires careful and systematic study.
(b) One effective evacuation technique is in effect a transfer from one compression chamber to another. An essential requirement for effective use of any evacuation technique is therefore that a dive system shall have compatible (standardized) locking-on facilities.

Pre-Planning before Emergency Evacuation

Legislation requires that provisions be made in diving rules in respect of evacuations. It is recommended that the following overall circumstances be separately considered in these diving rules and guidance on appropriate response be given:

Prevention

What are the particular risks in the diving operation from:

Extreme weather? Fire and/or explosion? Collision? Blowout?

What communication would vessel or drilling management or others have been established to communicate particular risk situations?

What measures can be established to minimise the risk from circumstances noted previously.

Will the proposed emergency action place the divers at even greater risk?

Items requiring continuing awareness

What is the weather forecast?
What support vessels are available and what time would be required for their arrival?
Where is the nearest compression chamber facility and is it compatible with the system on board?

CONTINUED ON PAGE 45