ORIGINAL PAPERS

SCUBA DIVING FATALITIES IN AUSTRALIA AND NEW ZEALAND

1. THE HUMAN FACTOR

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Background

The USA Underwater Diving Fatalities Statistics [1,2] have until recently been compiled almost single-handedly by John J McAniff, Director of National Underwater Accident Data Centre (NUADC), University of Rhode Island. These records, which go back to 1970, include more than 2,600 fatalities, and are unsurpassed in their scope.

In Australia and New Zealand (ANZ), the deaths are less numerous but data is more detailed and is comprehensively catalogued. It is collated as "Project Stickybeak", run by Dr Douglas Walker and the provisional reports with case histories are published[3] and made available to instructor and other supporting organisations. All material acquired is confidential and no identifying details are included in the use of this information to promote safer diving operations.

There is national cooperation in the supply of data in both Australia and New Zealand. Copies of depositions, police interviews, witnesses statements and inquest proceedings are supplied by the Law/ Justice / Attorney General's departments in each state. The Water Police, Police Divers and Navy Diving Units' reports include bench testing of the diving equipment used by the deceased, compared with the national standards for compressed air equipment, and often in-water trials where an experienced diver, of similar stature, employs the equipment in a simulation of the dive profile. Gas analyses are routinely carried out at government laboratories.

Because of the excellent publicity achieved by the people and organisations involved, virtually all ANZ diving instructors and dive shop proprietors, as well as most established divers, are aware of "Project Stickybeak". This ensures that few diving deaths are missed, and much more information may be collected than is available to other individual agencies.

This report is the first of three extensions of "Project Stickybeak", and deals with an analysis of the human factors contributing to the death. It encompasses medical information, psychological problems and various diving techniques that imply questionable judgement. The second extension deals with faults and misuse of equipment and the third with environmental factors.

Both authors have had many years (1967-1989) of investigating diving accidents and diving deaths, incorporating both the civilian and Armed Services diving activities.

Survey Material

In this ANZ survey, information was compiled on factors contributing to 100 consecutive scuba diving fatalities in this decade. The NUADC figures quoted for comparison were calculated from the 1980-1987 reports.

For diving fatalities to be included, the following requirements had to be met:
1. Scuba gear had to be worn by the victim in the water, with the intent of diving.
2. All military, large commercial or helium diving activities were omitted.
3. At least three of the following four sources of detailed information
   a. A coroners inquest or enquiry (full transcript including witnesses declarations and cross examination);
   b. Autopsy findings (anatomy, histology and toxicology in full detail);
   c. Official government (Navy, Water Police, etc.) assessment of equipment functioning and in-water trials. This includes gas analysis on scuba tank compressed air.
   d. Detailed written accounts of witnesses, (buddies, other divers, boatman or bystanders, rescuers)

As well as these, additional information was sometimes available from newspaper articles, underwater and diving agencies, including instructor organisations, private sources and rescue services.

Inevitably, judgements had to be made regarding the relevance of much data. Often there were minor or major abnormalities, mistakes, difficulties or problems encountered, which did not appear as if they were related to the incident leading to death. Unless stated otherwise, these have not been incorporated as contributing factors in this paper.

In the ANZ series all factors which were likely to have materially contributed to the sequence of events which led to death, or prevented action being taken which would have led to a successful rescue, were recorded.

The results were categorised as follows

DIVING DATA

This gives an overview of the diver, the type of diving, the behaviour of the diver and observers. Related

statistics from the NUADC data are supplied for general interest. We have not attempted to replicate the basic data of NUADC or Project Stickybeak.

MEDICAL CONTRIBUTIONS

These include psychological (e.g. panic, fatigue), physiological (e.g. vomiting, extreme physical unfitness) and pathological conditions (e.g. pulmonary barotrauma, drowning) leading to death.

DIVING TECHNIQUE CONTRIBUTIONS

Although this survey does not extensively analyse the diving data, certain diving procedures or techniques that involve human judgements and have been perceived as having an influence on diving deaths are recorded. These include diving experience, out-of-air situations, buddy diving, weight ditching and buoyancy problems.

EQUIPMENT CONTRIBUTIONS

These are subdivided into equipment faults and equipment misuse because, for example, it seems unfair to impute fault to the weight belt because it was misused, e.g. by being worn under the buoyancy compensator harness and thus failed to be ditched in the emergency.

If, however, the weight belt has no fault and is correctly worn, but is inappropriately (voluntarily) either ditched or retained so as to contribute to the accident, then this is rightfully attributed to poor diving technique or judgement, and is included in this report.

ENVIRONMENTAL CONTRIBUTIONS

These include both natural hazards (e.g. tidal currents, sharks) as well as non-scuba related man-made hazards (e.g. boats, dam outlets). In this paper the environmental contributions are not further categorised as they are the basis of a subsequent report..

If the diver had attempted to dive under conditions for which he was clearly untrained and inexperienced, then this is seen as an error of judgement and is referred to in this report.

Results and Conclusions

As there were 100 cases, each case represented 1 % of the total. Even where information was not available, the figures still represented a percentage of the 100 cases.

Diving data

Despite the different method of selection of cases, the NUADC and the ANZ series showed remarkably similar profiles of diving activities. In most cases the accident came as a great surprise to all associates of the deceased, but in 9 % the victim had been specifically advised by a diving medical expert, and sometimes by a dive instructor, that they were unfit for scuba diving.

Table 1. DIVER DATA

	NUADC	ANZ
Average age (years)	33.1 yrs.	32.9 yrs
First Scuba dive	5.4 %	8 %
Under training	9.0 %	5 %
Multiple deaths	9.8 %	4 %
Diving alone	17.5 %	21 %
Male/Female ratio	9:1	9:1
Age > 50	9.7%	8 %

Age. The age range was 13 to 65 with majority between 21 and 35, and a small increase around 46-50. The latter was related to the “cardiac deaths” which had their peak in this age group

Table 2. AGE INCIDENCE

Age	No
11-15	1
16-20	8
21-25	21
26-30	19
31-35	21
36-40	9
41-45	3
46-50	10
51-55	5
56-60	1
>60	2

Depths. The depths of the dive, the initiating problem and of unconsciousness (or death) are shown in table 3. A small number never descended at all, and over a quarter first encountered their trouble on the surface. Despite the wide range of diving depths, at least half either died or lost consciousness on the surface. In 14 % of cases the fatal dive was a repetitive one.

Duration. In 17 %, the diver succumbed in the first 10 minutes of the dive. In 56 % the problem developed following an exhaustion of the air supply (either on reserve or out of air). In 8 % it was intermediate between these times.

It would seem reasonable to conclude that, in planning a dive, accidents could be anticipated more often at the start or at the end.

Table 3 DIVE DEPTHS

Depth in metres	(ft)	Dive	First problem	Unconsciousness
Surface 0	(0)	3	28	50
1-3	(1-10)	4	3	2
4-6	(11-20)	13	10	7
7-9	(21-30)	12	3	5
10-12	(31-40)	12	4	4
13-15	(41-50)	9	5	3
16-18	(51-60)	7	1	1
19-21	(61-70)	7	-	2
22-24	(71-80)	4	1	1
25-27	(81-90)	6	3	4
28-30	(91-100)	1	1	1
31-45	(101-150)	5	-	4
46-60	(151-200)	3	4	3
69	(226)	2		
92	(302)	1		

Purpose. The purpose of the dive was recorded, but is not designated as a contributory cause in this presentation.

Table 4. PURPOSE OF THE DIVE %

Recreational dive	30
Hunting	30
Photography	7
Introductory dive	7
Work activity	6
Cave diving	5
Under instruction	5
Instructing	2
Wreck diving	3

Responses. Once a problem has developed, even though the surface was sought in most cases, the weight belt was rarely ditched and the buoyancy compensator (BC) was not inflated, either at the surface or at depth.

Table 5. BEHAVIOUR OF VICTIM %

BC	inflated	21
	not inflated	48
Weights	ditched	9
	not ditched	83

Table 6. BUDDY RESPONSE %

Assisted with air supply	11
Ditched victim's weight belt	12
Inflated victim's BC	10
Surfaced with the victim	12
Rescue and/or first aid	23
Buddy breathing failed	4

When the buddy remained with the victim, or eventually found him, there was usually an appropriate response. Only in one case did the rescuer become a victim.

Buddy breathing seemed to cause some problems, especially during ascent.

Overview of contributing factors

The number of contributory factors increased with the detail available of the dive. A "sole cause", such as a shark attack or an inexplicable burst lung, was a rarity, except in the divers who dived alone, when our records are probably not complete.

In allocating cases , each victim was recorded only once in each major category (Table 7).

As well as these contributory factors, certain diving techniques or activities were likely to have contributed to the final event. These are

Table 8. DIVING TECHNIQUES

Inadequate air supply	56%
Buoyancy problems	52 %
Other equipment misuse	35 %

Medical disorders

Cause of death. Even though an understanding of the events is not obtainable by autopsy findings alone, they

Table 7. MAJOR FACTORS

	NUADC *	ANZ Series		
		Probable	Likely	Total
Medical disorders	55.7 %	59 %	43 %	74%
Equipment faults	9.5 %	23 %	18 %	35 %
Environmental	34.8 %	52 %	18 %	62 %

* The results were not strictly comparable with the NUADC series, which had less information available on each death, did not use identical classifications, and only recorded one contributing factor and then in only 73 % of cases.

are indicative of the final event. The following results were derived from the conclusions from the autopsy findings, more than from the formal coronial findings.

Table 9. CORONER / AUTOPSY . Officially Designated Cause of Death

	ANZ	NUADC
	125 causes for 100 victims	
Drowning	86 %	74.2 %
Pulmonary barotrauma	13 %	24.5 %
Cardiac	13 %	9.1 %
Aspiration of vomitus	6 %	<1 %
Trauma *	3 %	1.5 %
Asthma	2 %	
Marine animal injury *	1 %	
Co-incidental**	1 %	

* Catalogued as environmental in the ANZ series
** The co-incidental cause was a dissecting aneurysm of the aorta.

In the final assessment only the past medical or physiological disorders which were thought to influence the death of the victim were included in table 10. Rarely was the past medical history available. For this reason, the "Pre-existing" figures must be considered as underestimates of the true situation.

In Table 10 cases marked with * were not recorded as contributing factors unless other related disorders co-existed. Excluding these, in 25 % of the cases there was a pre-existing medical contraindications to scuba diving. This compares to an overall "failure rate" of almost 10 %, during the 1980s, amongst recreational scuba divers who attended the Diving Medical Centres in Sydney (7).

Many of these factors were subjective, such as fatigue and panic, and we had to rely on witnesses descriptions. They are fortunately usually associated with other environmental, equipment or technique problems.

Salt water aspiration while the diver was still conscious, was likewise an unverifiable factor and relied on data from others. In most cases it was overtaken and pathologically obscured by its logical extension, drowning.

Patients who have had diabetes, epilepsy and cardiac surgery are, like asthmatics, excluded from diving suitability, both in the customary medical examinations and the signed declarations required by diving instructor organisations. This has not prevented them from settling in these statistics

Stress responses, fatigue and panic. These subjective symptoms are "soft" data that can only be presumed by a detailed description of the diving activities. Nevertheless, they occur frequently throughout the fatality case reports. To dismiss them because of the inability to demonstrate morbid pathology, would be to ignore two of the major contributory causes of diving deaths.[4]

Panic is a psychological stress reaction to anxiety. The threat of death is a reasonable cause of anxiety. Under selected circumstances, anyone will panic. Difficulty in obtaining air is a frequent cause of panic and the inhalation of water was associated with panic in 19 % of the cases.

Table 11. STRESS LEADING TO PANIC n = 39

Salt water aspiration	19
Fatigue	16

Fatigue is a physiological stress reaction to a muscular effort which was often underestimated by the victims. Under sufficient physical stress anyone can become fatigued. Salt water aspiration, panic and cardiac disease all occurred more frequently than would be expected in these cases.

Table 10. MEDICAL CONTRIBUTIONS
(Excluding drowning)

	Pre-existing	Probable	Likely	Total
Panic		31	8	39
Fatigue		23	5	28
Vomiting	1	6	4	10
Nitrogen narcosis		7	2	9
Drugs	*8	1	6	7
Very physically unfit	4	3	1	4
Severe disability	3	1	2	3
Severe visual loss	3	1	2	3
Alcohol		2		2
Motion sickness	2	1	1	2
Gross obesity	*8		2	2
Carotid sinus reflex		1		1
Salt water aspiration		22	15	37
Pulmonary barotrauma		10	3	13
Cardiac disease	3	7	5	12
Asthma	9	6	2	8
Respiratory disease	5	3	4	7
Hypothermia		1	2	3
Hypertension	*8		2	2
Ear problem	2	1	1	2
Diabetes	1	1		1
Others		1		1
Epilepsy	1			
Decompression Sickness				nil
Contaminated air supply				nil

* = not recorded as contributing factors unless other related disorders co-existed.

Table 12. FATIGUE (28 cases)

Salt water aspiration	18
Panic	16
Cardiac disease	9
Nitrogen narcosis	3
Severe disabled	2
Hypothermia	2
Very physically unfit	2

Vomiting. After exclusion of those cases in which vomiting happened after removal of the victim from the water or as a terminal event, it initiated or complicated the event in 10 % of the cases.

Table 13. VOMITING (10 cases)

Salt water aspiration	4
Regulator leaking	3
Sea sickness	2

Nitrogen narcosis. This contributed to the death in 9 % of cases, but was never the sole or major cause.

Drugs. Alcohol, carbon monoxide and narcotics were tested during the autopsy in most cases. Otherwise the information was obtained fortuitously, and therefore be an underestimate. Cannabis was used once, but was not considered a contributor (Table 14).

The relationship between alcohol intake and drowning is well described elsewhere.[5] The higher incidence of cardiac deaths amongst those with hypertension and treated with hypotensive drugs, is probably also predictable.

Salt water aspiration. While still conscious, this was present in 37 % of cases and was a interim factor, following some other event such as using a snorkel in white water or an out of air situation. Problems with the regulator occurred in 12 cases and were therefore unexpected. The result of the inhalation of water is seen in the associations between this and other medical contributions.

Table 14. DRUG INTAKE

Illness	Number	Drug	Cause of death
Asthma	9	Salbutimol	Pulmonary barotrauma (2)
			Drowning (7)
			Cardiac (1)
Hypertension	5	Hypotensives	Cardiac (4)
			Drowning (4)
N/A	4	Alcohol excess	Drowning (4)

Table 15. SALT WATER ASPIRATION
n = 37

Panic	19
Fatigue	18
Cardiac disorder	9
Asthma	6
Hypothermia	3

Pulmonary barotrauma. This was evident in 13 % of cases. In some cases the extensive pulmonary damage was obvious, but in others it was complicated by the effects of subsequent drowning. The clinical presentation of classical cerebral arterial gas embolism was considered adequate to make the diagnosis even without pathological verification.

The suddenness of these cases made other observations more difficult, however some associations were noted.

Table 16. PULMONARY BAROTRAUMA
n = 13

Panic beforehand	5
Nitrogen narcosis	3
Emergency ascent	2
Asthma	2

Cardiac disease. Of the 12 % of divers who died of cardiac disease, there was 2 cases of myocarditis, pathologically demonstrated and in young divers who had intercurrent illnesses. The average age was 43.6 years, (S.D.= 7.6). The mode was in the 46-50 years age group, with 5 deaths, and 3 between 51-55 years. They did tend to die quietly.

Three had a history of heart disease and another four of hypertension requiring treatment. With so many possible trigger factors (previous pathology, exertion, cold exposure, prescription drugs including beta blockers, hypoxia from aspiration of sea water, etc.) for both myocardial ischaemia and ventricular fibrillation, it would be hard to incriminate one specific aggravating factor.

Table 17. CARDIAC DEATH
n=12 *

Salt water aspiration	9
Fatigue	9
Drugs	5
Hypothermia	2

* In accepting this diagnosis we have required very gross pathology or an excellent clinical description. If we were to accept all autopsy and clinical diagnoses of cardiac disease, the number would have risen to 21.

Asthma. In no case was the diagnosis of asthma made purely on the basis of histological findings. There is a 24 hour delay in the production of the characteristic eosinophilic infiltration and desquamation changes with an acute attack of asthma.[6] This could well have reduced the apparent influence of this illness, but it was somewhat compensated for by the ability of some of the pathologists to detect and record the chronic signs of asthma.

Of the 9 % who had asthma, the following information was found:

Table 18. ASTHMA
n = 9

Autopsy cause of death	
drowning	7
pulmonary barotrauma	2
Medical contributions	
salt water aspiration	5
fatigue and/or panic	5
Technique problems	
compromised air supply	6

When the factors for asthma provocation in scuba diving are considered, namely ;

exertion
inhalation of cold, dry air
hypertonic saline inhalation

and it is realised that each of these stresses are used clinically to initiate asthma as a diagnostic provocation tests[6] the high incidence of this disorder is understandable.

It is not known whether breathing against an increased inspiratory resistance (low on air) is also a provoking factor, but this should now be considered in the light of these figures.

Respiratory disease. Four cases of the seven had respiratory infections and two had pleural adhesions (one from a thoracotomy, and one who died with pulmonary barotrauma, pneumothorax and a large haemothorax). Dyspnoea on walking on the flat and a Peak expiratory flow rate of 320 litres per minute, were considered evidence of probable respiratory disease.

Diving techniques

An assessment of certain dive procedures was made as regards both the frequency of these in fatal diving accidents and their contributions to this. As we have no idea how often they have saved lives in other circumstances, these figures should not necessarily be used to condemn any practice, but at least to review it.

Experience. The fatal dive being undertaken was compared in complexity to the diver's training and previous experience.

Table 19. EXPERIENCE

Nil experience	8 %
i.e. never scuba dived before	
Inadequate	39 %
Consistent	43 %
Excessive	6 %

Air supply. As 56 % of the problems developed after the air supply had reached reserve levels (low on air and out of air), it could reasonably be concluded that the divers found it more difficult to handle problems under those conditions. This tallied with the observations on the number of "surface" deaths, and the problems of coping with surface swimming conditions.

Table 20. AIR SUPPLY

Snorkel breathing on surface	8 %
out of air or low on air noted on surface	7 %
out of air or low on air noted at depth	49 %

Most problems develop from the time the victim became aware that the air supply was compromised. To avoid unnecessary air consumption, snorkelling on the surface was employed and coincided with the development of problems in 8 % of cases. One of the other ways of producing a low on air situation was by the victim using either a cylinder smaller than normal or a cylinder with less than customary air pressure (9 %). Most had contents gauges.

In the case of the small cylinder, not only was there less air supply than that available to the other divers, but when the low on air situation developed the actual amount of reserve air was much less than usual. In some of the cylinders, holding only 28 cu ft, there was only a few breaths of air once the low on air situation was reached at depth.

Buddy diving. The buddy system, which has universal support amongst recreational diving groups and instructors, appeared to have more verbal than factual acceptance. The divers were therefore assessed, not according to their statements, but according to what happened during the dive. Many alleged buddies were divers who only shared the same boat.

Over a third of the victims were either diving alone or separated voluntarily before the problem developed. One quarter voluntarily separated afterwards!

Table 21. BUDDY BEHAVIOUR

Nil. Solo from start.	21 %
Voluntary separation	
before any problem	13 %
Voluntary separation	
after a problem commenced	25 %
Separation by the problem	20 %
Not separated	14 %

By far the most common reason for the separation was that one diver (the subsequent victim) ran out of air or low on air, and the buddy decided not to interrupt his diving activities because of this. Occasionally the buddy accompanied the victim to the surface and then deserted him.

The problems that sometimes separated the buddies were uncontrolled ascents, underwater and surface currents, sometimes sudden and unexpected. In only 14 % did the buddies remain together.

Table 22. BUDDY DIVING VARIANTS

Two or more buddies	15 %
Victim follows the buddy	5 %
Victimisation of buddies	2 %

Amongst the small numbers that were classified as buddy divers, there were some practices which seemed to detract from the buddy concept. In 15 % there was not one

buddy, but two or more. This led to considerable confusion as to who exactly was responsible for whom.

In 6% the victim was following the "buddy". Once a problem developed under this system, any observation by the lead diver would have been be fortuitous. To attract the lead divers attention required energy, air and time consuming behaviour on the part of the victim, who could ill afford these commodities once the problem developed. The experienced diver was invariably the one who took the lead, and therefore had the luxury of a buddy observing him at all times.

In two instances there were groups of people being led on a dive. The procedure used was that the first diver to exhaust his air supply would inform the dive leader that he was now "on or near reserve". The dive leader would then take time to determine who else was in or close to a low on air situation. These two divers were then buddied, to surface and return to base.

Thus the dive leader managed to select the two heaviest air consumers, and usually the two least experienced divers, and buddied them together into a situation in which either one was likely to develop a complete out of air situation during ascent , while performing a safety stop, or on the surface. This seemed to be an accepted practice in "resort " areas.

Weight belts. As in previous surveys it was found that very few of the victims, only 9 %, successfully ditched their own weight belts.

Table 23. WEIGHT BELT CONTRIBUTIONS %

Too heavy	45
Not ditched by victim	40
Fouled or unreleasable	6

In 83 % the weight belt was not ditched by the diver and in 40 % this probably contributed to the victim's death. In 3 % it was fouled by being worn under other equipment harnesses. It was unreleasable in 3 %, because of, entanglement with lines, the weight slipping onto the quick release buckle, or the strap being too long and jamming the release on the belt .

Failure to ditch the weights, when in difficulty, presumably reflects on training techniques.

Buoyancy / BC. Many of these problems came under the equipment category, but an appreciable number were clearly errors of judgement and were therefore included as faults in diving technique.

The wet suits available for most of this decade required; 1 Kg weight for each 1 mm thickness, 1 Kg extra for "Long John" extensions and a hood, 1Kg for aluminium tanks, and an extra 1 to 2 Kg for individual variation in buoyancy. In excess of this, the diver was considered to be overweighted and to require extra effort, hyperventilation or reliance on the BC, to remain buoyant on the surface.

Using these criteria it was found that 40 % of the divers were overweighted on the surface. At depth the problem of overweighting was compounded by the loss of buoyancy from the wet suit and body spaces. There is then a much greater effort required for surfacing.

Reliance on the BC inflation then becomes not just a convenience, but an essential.

Apparently many divers have replaced the skills of buoyancy control with heavy reliance on the BC. They are purposely overweighting "to get down", and the BC is inflated to return to the surface. In these cases the BC is relied on not to trim buoyancy with depth, but to return the diver on the surface. Such a procedure introduces the potential for accidents.

Table 24. BUOYANCY CONTRIBUTIONS

Negatively buoyant	
>2 kg on surface, without BC use	40 %
Negatively buoyant	
>2 kg at depth, without BC use	7 %
Positive buoyancy due to BC usage	8 %
TOTAL	52 %

The BC problems included;
- accidental inflation,
- confusion with use (two victims repeatedly confused inflation with dump valves),
- overinflation during ascent (Boyles's law and the Polaris effect),
- inadequate and very slow inflation at depth (especially in a low on air situation)[7],
- mechanical failures and malfunctions,
- ditching problems with some types (involving inflator hoses and harnesses),
- effort required to overcome drag when swimming underwater and on the surface.

Discussion

BACKGROUND

Recently, the purported low death rates in the 1980s were shown to be based on overly optimistic figures and creative statistical interpretations.[8-10] So also was the alleged improvements in safety amongst scuba divers.

These death rates of 16-20 per 100 000 now being proposed, together with the increased death rate per dive increasing to 1 in 95,000, have compelled both the NUADC and the instructor organisations to review and appreciably modify their claims of safety.

The NUADC and Project Stickybeak have conscientiously recorded the number of diving deaths, and this survey extends that effort to understand why such deaths occur.

The ANZ series requires extensive detail of each death. The NUADC records only one cause of death (usually drowning) and, sometimes, one initial contributing problem.

The ANZ series defines all the known contributing adverse factors. It differentiates medical disorders, diving techniques, equipment faults and misuse, and environmental factors.

Consider the case in which a diver descends to 50 metres (165 ft), becomes narcotic and uses all his air. Attempted buddy breathing results in his face mask being accidentally displaced. He then panics. As he commences his ascent he decides to not ditch his weight belt but to rely on his BC. The air in the BC expands rapidly and causes a totally uncontrolled "polaris type" ascent during the last 10 metres. As he hits the surface he gets run over by his safety boat, which could not swerve in time. The diver is knocked unconscious and his BC is damaged in the collision. As he retained his weight belt, the diver sinks to die of drowning.

To record this as "Drowning", even if complemented by one "probable starting cause", is a gross oversimplification of a complex series of interactions, and ignores the many contributing factors, which may have implications for diving safety and instruction.

There are a variety of contributing factors in this example; depth, narcosis, out of air, buddy breathing during ascent, loss of face mask, panic, uncontrolled ascent due to air expansion in the BC, injury from the boat, and the decision not to ditch the weights, are all relevant. These would all be included in the ANZ survey.

Due to the changes that have taken place in scuba equipment and techniques, during the 1980s, this paper is restricted to diving deaths during this decade. The NUADC statistics are similarly restricted to scuba deaths in this period.

DATA COLLECTION

The ANZ cases demonstrate that although diving may be safe under most circumstances, when a number of adverse factors combine, the diver is often unable to cope with the complexities of his equipment and environment.

Although comparisons to the NUADC surveys are inevitable, the populations and the survey data are not really comparable. Press clippings provide the greatest number of cases for the NUADC, and although this may be adequate for deriving gross morbidity figures, it is not adequate to explain the deaths.

The NUADC had coroner findings or autopsy results in 64%. These appear to refer to the official statements or summaries, as opposed to the full transcripts. We have not found these summaries to be sufficiently informative for our purposes of identifying contributing causes.

There is a wide difference of knowledge and expertise amongst officials. Coroners' and other government inquiries are also frequently characterised by naivety in their tendency to oversimplification of "the" cause of the accident, instead of an understanding of the dynamics of the events. They are also influenced by possible criminal responsibility, litigation implications or liability of their statements.

Sometimes autopsy observations are misinterpreted. As a common example, air embolus and decompression sickness have been diagnosed because of the presence of air in the heart and blood vessels. If this air is in the right ventricle, as well as the left, the diagnosis must be questioned. Air can develop in the heart and vessels as a post mortem artifact[5] in divers who have been breathing compressed air at the time of their death ("post mortem decompression sickness").

In most cases of unconsciousness or disablement and and subsequent death while diving, drowning is a common sequel to the loss of the air supply. The pathology of drowning may then dominate the autopsy findings, even though it is not the initial cause of the problem, but only "the final event". For this reason, drowning is not considered an adequate explanation for death in divers, but a common sequel to loss of consciousness underwater.

MEDICAL CONTRIBUTIONS

The fact that some divers were known to have been specifically told by diving experts that they were unfit to dive, suggests that sometimes good advice goes unheeded.

Despite the absence of comprehensive medical examinations in most, and the absence of any premorbid medical data in more than half the cases, it was evident that at least 25 % of the divers were medically unfit to undertake scuba diving, on history alone.

A large number of asthmatics and hypertensives on treatment, as well as the cardiac patients, a diabetic on insulin and an epileptic, are represented in this series. Their presence is incomprehensible, considering that the candidates are required to pass special medical standards for diving, as well as complete a screening questionnaire issued

by the diving instructor organisations. The physicians and the instructors are not applying these standards.

A recent report[11] suggests that the failure of Australian physicians to apply the medical standards, is due to ignorance of these standards and a failure on the part of the physician to appreciate the problems of scuba equipment and the demands of the ocean environment. The reasons for the instructors not applying the standards is not known.

In either case, the current system has not succeeded in selecting out the high risk patients. Physicians and dive instructors are still confusing physical fitness (needed for many sports) and medical fitness (a freedom from medical diseases incompatible with safe diving). Both are required. Many of the deceased divers were said to have been very fit physically, despite having such medical diseases.

If drowning is excluded as only the final event in a sequence of adverse happenings, then the stress problems of panic and fatigue dominate the medical contributions. Because these do not feature in autopsies, they are not fully appreciated in some series. They are interwoven with faults in technique (or training), and with many equipment and environmental provocations.

The importance of these stress factors is contrasted with the great rarity of the high profile diving diseases of decompression sickness and gas contamination, which were absent in this series and noted in less than 1 % of the NUADC series.

The importance of other major contributors that leave little or no evidence at autopsy, such as salt water aspiration, nitrogen narcosis, drug intake, vomiting and asthma, can only be comprehended by a detailed dive history. These do not show up as much in the NUADC series, because of the limitations of the data collection and the decision to only include one contributing factor in most cases.

The NUADC and ANZ series show reasonable agreement on the importance of pulmonary barotrauma and cardiac disease. The latter seems to be an increasing problem. The importance of astute medical selection and then adequate training of divers is axiomatic in the prevention of these.

DIVING TECHNIQUES

In an assessment of diving techniques that imply questionable judgement, we are encroaching on diver training more than diver selection.

The inexperienced and overconfident male was overrepresented in both the NUADC and ANZ series. Diving well within the limitations of the diver, and the equipment, was not a well practiced activity amongst these divers.

The majority who die do so after voluntarily inducing a compromised air situation. They are then forced to surface to breath, or to conserve their emergency air supply. Returning with plenty of air was not common.

The traditional admonition that the surface is the danger area for divers, was supported by the figures showing that at least half the cases lost consciousness and died there. Nevertheless the surface was unavoidable in 56 %, as the diver was in a compromised situation as regards his air supply.

The surface problems were frequently aggravated by the decision not to ditch weights. This also contributed to many of the cases that developed at depth, where a failure to appreciate buoyancy factors resulted in excessive exertion being required.

The training technique of older experienced instructors to require trainees to practice removal and replacement of the weight belt on each dive, could well be resurrected. This practice alone may have prevented the deaths in which the belt was eventually unreleasable.

Instruction to unbuckle the weight belt and hold it at arm's length in all demanding situations, was either not taught or not applied in any of these cases. Yet, had this been done and the situation deteriorated, the belt would have been dropped successfully and the diver made positively buoyant, assisting slow ascent and permitting surface swimming without being overweighted. If the situation had not deteriorated, the diver could have replaced his belt without penalty.

The extreme effort in swimming on the surface with scuba gear, heavy weights and an inflated buoyancy compensator[12], seemed not to be widely appreciated amongst this diving population.

The technique of overweighting, "to get down", and the subsequent strong reliance on the inflation of the buoyancy compensator[7] to ascend and remain on the surface, presumably makes instruction much easier. The failure to learn the skills of buoyancy control[13], without an over-inflation/over-weight trade off, is an expensive lesson not to learn. Dependency on equipment may well be related to the failure to ditch it in an emergency.

Buddy diving, as envisaged in the manuals, is a rare event in these cases. The majority of divers dived alone, and died alone.

Even in the NUADC reports, less than half dived as a buddy pair, and only a quarter stayed together. The ANZ series shewed that a third claimed to try to stay together, and only one seventh actually did. The relatively slight differ-

ences in the numbers probably is explained by the greater dive detail in the ANZ cases.

It seems as if the buddy concept, if used at all, was mainly employed when it was not needed. More buddies voluntarily separated from the victim at the start of problems (usually when low on air) than actually stayed together.

Even when it is applied, the less experienced diver, or the one who will consume more air, is initially given the task of following the more experienced divers until he runs out of air and he is then sent to the surface to swim back alone! Or he is buddied with another low on air diver.

Traditionally, companion diving was recommended and the need was self evident because of the recognition that diving was a hazardous activity. As diving is now promoted as being a safe sport, perhaps the need for companion diving is less appreciated. For uneventful dives this attitude may be adequate. For others it is not.

The observations in both the NUADC and ANZ fatality series for the 1980s, should emphasise the need for buddy diving, in which the divers do genuinely take responsibility for each other for the whole time, until they return to shore or safety. It needs to be taught, understood and practiced.

Conclusion

The real tragedy of this survey was that it shows that the lessons and teachings of yesterday, are still not sufficiently appreciated today. The requirement for a high standards of physical fitness as well as a freedom from many medical diseases, together with training in accident prevention and management, an appreciation of the limitations of equipment and a healthy respect for a potentially hazardous environment, are as important for safe diving now as they ever were.

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PROVISIONAL REPORT ON DIVING-RELATED FATALITIES AUSTRALIA 1987

Douglas Walker

Summary

There were four breath-hold and four scuba diving deaths identified as having occurred in Australian waters during 1987. A common finding in all was that the victim was either diving alone or was separated from others at the critical time, though this was not a invariably a factor which determined the course or outcome. Three of the breath-hold