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HAWAIIAN SCUBA DEATHS

Carl Edmonds and Roy Damron

Background

During the 1980's a number of surveys were carried out on the causes of recreational scuba diving deaths. Also, the death rate in recreational divers was revised upwards.[1] Previously and also during that time the National Underwater Accident Data Center (NUADC), under the control of John McAniff carried, out annual surveys on the causes of diving deaths.[2,3] NUADC have recorded almost 3,000 fatalities, but the documentation relies heavily on second and third hand information. Nevertheless the great numbers ensure that the information is of value. More recently the Divers Alert Network (DAN) has also become involved in the compilation and analysis of diving deaths in Northern America.

In the Australia and New Zealand survey (ANZ series), by Edmonds and Walker[4-6], the deaths were less numerous, but more data was available and it was far more comprehensively catalogued. It included, as a routine, comprehensive police reports, autopsy details, equipment analyses and re-enactment trials. The information so obtained was used as a basis for a series of reports showing the factors contributing to death, and not merely the "final" cause.

This paper covers a number of scuba deaths in Hawaii over the same period. It is reminiscent of the NUADC reports, relying more on newspaper and unofficial reports than did the ANZ series.

It is hard to quantify the relative amount of material available in the three series. The ANZ series had far more detail than either of the American series. The Hawaiian series may well be a little more comprehensive than the NUADC reports because of the simpler logistics of obtaining information from within a single State of the USA, as opposed to trying to obtain information from all States and overseas.

Methods

These case files were compiled by one of the diving experts in Hawaii (RD), initially obtained from newspaper reports but supplemented with follow up investigation, both on an official and personal level, to ascertain more details. The analysis was then made by an independent expert in this field (CE).

Diving deaths data

For the 80 deaths, the data was often not complete and therefore the percentages recorded are those of the number on which that specific data was available, usually not of the total 80 cases. The data available from this survey does give some appreciation of the population being studied.

Approximately half the deaths were in divers aged below 30. Another third were aged between 31 and 40. None were over 60 (Table 1). The great majority of the deaths were in males. Only eight out of the eighty (10%) were females.

Diving qualifications were not always recorded. This information was available for 53 (66%) of the 80 deaths (Table 2). Three died on their first dive; one alone and two with companions whose diving expertise was unstated. Although 15%died while under instruction during their basic "open water" diving certificate training, this figure

TABLE 1

AGE DISTRIBUTION OF DEATHS

11-20	5	(6%)
21-30	34	(43%)
31-40	22	(28%)
41-50	10	(13%)
51-60	8	(10%)
Total	**80**	**100%**

TABLE 2

QUALIFICATIONS

Initial dive	3	(6%)
Under basic training	8	(15%)
Not certified	10	(19%)
Certified	30	(57%)
Professional	2	(4%)
Total	**53**	

TABLE 3

EXPERIENCE LEVELS

Inexperienced	(0-6 dives)	18	(33%)
Moderate experience	(7-30 dives)	13	(24%)
Experienced	(>30 dives)	24	(44%)
Total		**55**	

TABLE 4

DIVING ACTIVITY

Recreational diving	25	(39%)
Under training (basic and advanced)	10	(16%)
Spear fishing	10	(16%)
Diving for black coral	8	(12%)
Crustacean collecting	3	(5%)
Photography	2	(3%)
Tropical fish collecting	2	(3%)
Scientific diving	2	(3%)
Fish feeding	2	(3%)
Total	**64**	

TABLE 5

BUDDY SYSTEM

Diving alone at all times	12	(16%)
Separated voluntarily before the accident	23	(32%)
Separated voluntarily after the accident	10	(14%)
Separated by the elements or the accident	14	(19%)
Stayed together	14	(19%)
Total	**73**	

TABLE 6

DEPTH OF THE ACCIDENT

0-3 m	30	(48%)
3-9 m	14	(23%)
9-30 m	10	(16%)
>30 m	8	(13%)
Total	**62**	

TABLE 7

MAXIMUM DEPTH OF DIVE

0-3 m	3	(4%)
3-9 m	37	(50%)
9-30 m	19	(26%)
>30 m	15	(20%)
Total	**74**	

TABLE 8

DURATION OF THE DIVE

Within the first 5 minutes	8	(14%)
At the end of the dive, after a low-on-air or out-of-air, (compromised air supply) situation	32	(54%)
During the intermediate part of the dive	19	(32%)
Total	**59**	

might have dropped to 10% if information was available on all cases.

In the 55 cases where the number of dives that the diver had done were recorded it was possible to group the degrees of experience (Table 3). A separate assessment was made to determine whether the diver was experienced enough to undertake the dive during which which he ultimately died. It was decided that 30 (58%) were not experienced enough to undertake the fatal dive, whereas 22 (42%) had sufficient experience.

Many different activities were carried out during the fatal dive by the 64 divers for whom this information was available (Table 4). The buddy system was more honoured in the breach than in the observance (Table 5).

When the depth of the accident was recorded nearly half occurred in the surface to 3 m zone (Table 6). In 10 (16%) the accident developed during ascent. When the depth of the dive was recorded the majority of the divers were shallower than 9 m (Table 7).

In only 59 cases was there information about when the accident happened. In over half of these the accident happened at the end of the dive, after a low-on-air or out-of-air, (compromised air supply) situation (Table 8).

Causes of Death

The causes of death were assessed for all 80 fatalities. At least 49 (61%) appeared to have died from drowning. At least 12 (15%) suffered pulmonary barotrauma, with or without cerebral arterial gas embolism. At least 7 (9%) died from the Sudden Death (cardiac) Syndrome.[7,8] Four (5%) died from decompression sickness following the dive. Trauma (injuries by boats) was responsible for 3 (4%), as was coincidental medical illnesses (cerebral haemorrhage in one instance, epilepsy in two.) In 2 of the cases (3%) there was a previous history of loss of consciousness at depth. This was also thought to be a contributory factor to death in both those cases.

Factors contributing to death

The percentages in this section are of the 80 deaths.

HUMAN FACTORS (44%)

In 35 deaths (44%) significant human factors (medical disorders, physiological or psychological problems) contributed to the death, or prevented successful rescue and resuscitation.

Panic was noted in 16 cases (20%). Salt water aspiration was present in 9 (11%). Fatigue was noted in 5 (6%). Vomiting was present in 4 (5%). The following conditions were also noted, epilepsy in 2, nitrogen narcosis in 2, cramps in 1, cerebro-vascular accident in 1, cardiac disease in 1, chest infection in 1. Two divers were physically impaired.

Although there was very little medical information available on the majority of the divers, it was evident that at least 8 (10%) of them should have been classified as permanently medically unfit for diving because of their significant illnesses. As well as these, in 7 (9%) there was evidence of significant drug taking, and 5 (6%) had evidence of significant alcohol ingestion.

At least 14 (18%) were in the US armed forces at the time of the accident, although none were on active duty at the time of death.

EQUIPMENT FACTORS (40%)

In 32 (40%) cases, equipment either contributed to the death or prevented adequate rescue or resuscitation. In 11 (14%) there was an actual fault in equipment. Most of these failures (6) occurred with the buoyancy compensator. As well in 2 cases the regulator failed, in 1 the hose burst, in 1 the pressure gauge gave a totally misleading reading and in 1 the harness failed.

In 9 (11%) cases there was evident misuse of equipment. This was commonly associated with weight belt, harness or tanks. In 8 (10%) cases there was entanglement with lines, ropes, weight belt or harness.

In 20 (25%) cases, there was a failure to carry equipment which would have probably prevented the accident or allowed the diver to be rescued. In 13 cases (16%) there was no buoyancy compensator. Four divers did not wear a wet suit (5%),while 4 did not have a snorkel (5%). Not having a direction line in a cave led to the death of one diver, while the lack of a reserve lever for a J valve contributed to another. Some divers were without more than one life saving piece of equipment.

ENVIRONMENTAL FACTORS (56%)

In forty five deaths (56%) environmental factors contributed to death or prevented rescue. By far the commonest problem was related to water movement, either in the form of white water (reduced visibility, reduced buoyancy, increased water speed, trauma, etc.) or from waves, surf and tidal currents. In 32 of the 80 cases (40%) water movement contributed to the death.

The next most common environmental contributor was depth. Depths in excess of 30 m were required before a death was included in this category, but even then they were only so classified if it was thought that the depth itself was a definite contributor. This was so in 7 (9%) out of the

80 cases. Nitrogen narcosis or a loss of air supply contributed to most of these deaths. Depth was not specifically incriminated as a contributing factor in the deaths from decompression sickness, even though it obviously was a factor.

In 4 of the 80 (5%) cases, impaired vision associated with night diving, was a contributing factor. In 3 of the 80 deaths (4%) the diver was run over by a boat, and in 2 of these it was his own "safety boat"!

There was evidence of shark attack in two cases, but it was not clear whether the attack caused death or occurred after the death.

Techniques contributing to deaths

COMPROMISED AIR SUPPLY (36%)

Incorrect technique contributed to many of the deaths. In 29 of the 80 cases (36%) the fact that the diver had a compromised air supply lead either directly or indirectly to death. In some of these the diver had reached reserve levels, and therefore had to take the action which caused the death, whereas in others the diver seemed to have inadequate air at depth.

BUOYANCY (27.5%)

With 22 of the 80 cases (27.5%) there were significant buoyancy problems which contributed to the death. Of these 19 (24%) were due to negative buoyancy and 3 (4%) had catastrophic positive buoyancy problems.

BUDDY DIVING

Buddy diving techniques were not carried out in most cases. In 42 deaths (52.5%) the failure to comply with the buddy system was a significant factor in preventing rescue and first aid. In 3 of these cases the buddy was in an invidious situation, being the dive leader of a "follow-me" team , who could not possible have been aware of the victim's state until it was too late.

In 2 deaths there was attempted buddy breathing during ascent.

DITCH AND RECOVERY

In one case a "ditch and recovery" training technique was the direct cause of death.

Conclusions

The data available on this population suggests that the Hawaiians were a very similar group of divers to those in both the ANZ and NUADC series, and also to that reported in the general diving medical literature.[7] Specifically the high incidence of males compared to females, the surprising number of divers who died either during their initial dive or while under training, the observation that approximately half were experienced enough to undertake the dive and the neglect of the buddy system, was consistent in all three series.

About half had an accident either on or near the surface, but there was a greater number in the Hawaiian series who had dived to depths in excess of 30 m. All three series showed that accidents tended to happen at the start of the dive or following a compromised air supply situation.

The causes of death were very similar in the three series, with drowning the dominating diagnosis as a final cause of death. The only way in which this series differed was in the higher incidence of death from decompression sickness (5%), compared to the 0-1% in the other series. This tended to correlate with extremely deep diving and black coral collecting.

The factors contributing to death were consistent with the NUADC reports but were not of the same magnitude as the ANZ series, as would be expected because less data was collected.

Human factors contributing to death were seen in 44% of cases compared to 55.7% (NUADC) and 74% (ANZ).

In 40% of cases, equipment problems contributed to the death. In 14% the equipment was faulty; in 11% it was misused, while entanglement in equipment was present in 10%. In 25% adequate equipment was not available. This compares with equipment faults in 35 % and misuse in 35 % (with considerable overlap) in the ANZ series.

Environmental factors contributed to the death in 56% compared to 34.8 % (NUADC) and 62 % (ANZ). These incidences probably reflected the amount of data available.

The contribution of various diving techniques in the Hawaiian series was similar to the ANZ series. Unfortunately these categories are not easy to compare with the NUADC series. In 36% a compromised air supply contributed to the death. Buoyancy problems contributed in 27.5% and in 52.5% the failure to comply with the buddy system either contributed to the death or resulted in rescue being excessively delayed.

There are other specific references to Hawaiian diving accidents in the diving literature.[9-11]

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A PRELIMINARY REPORT ON A PROSPECTIVE RANDOMIZED, DOUBLE-BLIND, CONTROLLED STUDY OF OXYGEN AND OXYGEN-HELIUM IN THE TREATMENT OF AIR-DIVING DECOMPRESSION ILLNESS

Alison Drewry and Des Gorman

Abstract

The treatment of Australasian recreational divers with decompression illness using the United States Navy recompression algorithms has a high failure rate. Oxygen-helium gas mixtures may have some advantages over oxygen alone in such therapy, and consequently, a prospective randomized double-blind controlled study of oxygen and oxygen-helium in the treatment of air-based decompression illness has been initiated at the Royal New Zealand Naval Hospital in Auckland. Thirty patients have been studied in the first 4 months of 1992.

Introduction

The treatment of recreational air-divers with decompression illness (DCI) in Australasia is largely based on the "minimal recompression oxygen" tables promulgated by the United States Navy (USN) in 1965.[1] Although the USN, both initially and still, reports high resolution rates with the use of these treatments in its own naval divers,[2,3] this is not the current experience in injured recreational divers in Australasia. Failure rates (incomplete resolution of symptoms and signs) vary between 37% in Melbourne (1991; 100 divers),[4] 32% (neuropsychiatric sequelae) and 48% (abnormal EEG recordings) in Sydney (1987; 87 divers),[5] 54% in Auckland (1990; 125 divers)[6] and 54% in Adelaide (1988; 64 divers).[7] These failure rates do not vary significantly between facilities and the total number of patients treated and surveyed is large. It is also noteworthy that these failure rates exceed those reported in 1964 for both the 30 and 50 msw oxygen-nitrogen (air) recompression treatment tables.[8] Although these injured USN divers and their follow-up are not directly comparable with the nature and assessment of contemporary injured Australasian recreational divers,[4,5] the "high" failure rates reported in 1964[8] were used to justify the development of the 1965 alternatives (those in current use)[1] The same arguments then, used to introduce these "minimal recompression oxygen" tables can now be used to justify the development and testing of alternative therapies, at least for the treatment of recreational divers in Australasia.

The "minimum recompression oxygen" tables are a compromise between ambient pressure and oxygen toxicity, however the use of 2.8 bar inspired oxygen tension is nevertheless toxic to the injured brain.[9] An alternative is to use oxygen-helium mixtures at the same or greater ambient pressures, but such that the inspired oxygen tension is kept between 1 and 2 bar. The ideal inspired oxygen tension for treatment of DCI in vivo is 2 bar[10], but the optimal dose of oxygen to inhibit bubble-induced polymorphonuclear leucocyte (PMNL) accumulation (see below) has not yet been determined.[11] Although some studies of cardiopulmonary decompression illness in dogs and guinea pigs have failed to demonstrate any advantage,[12,13] oxygen-helium breathing has resulted in faster shrinkage of air bubbles in rat adipose tissue [14] and spinal cord white matter[15] than when either air or oxygen are breathed. This is explained by net gas flux being determined by both gas solubility and diffusion. Importantly, there is no evidence that oxygen-helium breathing causes air bubbles to grow in aqueous tissues such as