Surgeon Commander D.F.Gorman, BSc, MB ChB, FACOM, FAFOM, DipDHM, PhD is Director of Medical Services, Royal New Zealand Navy, Consultant to the Royal Australian Navy and Consultant to the Royal Adelaide Hospital. His address is RNZN Hospital, Naval Base, Auckland 9, New Zealand.

REFLECTIONS ON DIVER FATALITY AND SAFETY STATISTICS

Drew Richardson

Every death of a scuba diver is a human tragedy that diminishes the whole of scuba diving. Stories about diving fatalities remind us of the importance of established safety guidelines.

The thought of a person dying while scuba diving should cause us to think about our own mortality, diving practices and dedication to safety. We want to know why the accident happened. We search for the reasons to give us perspective, understanding and control.

When combined, proven diving practices and sound judgment afford a reasonable envelope of safety in which to dive. When rules are broken, limits stretched or ignored, we increase our risk. Occasionally, factors beyond our control compound the difficulty of a dive, leading to stress and in the extreme, death. Fatality statistics are an important barometer on the safety of our sport and the adequacy of our controls.

By carefully studying the causative factors leading to diving deaths, we help educate ourselves to avoid repeating tragedy. An excellent source of this information is produced annually by Divers Alert Network (DAN).

The National Underwater Accident Data Center (NUADC) at the University of Rhode Island, USA, has been reporting diving fatalities since 1970. Beginning in 1989, DAN has collaborated with NUADC in reporting diving fatalities. The data used in this paper are drawn from the 1991 and 1992 DAN Reports.[1,2]

In the past 23 years a total of 2,404 U.S. recreational scuba fatalities have been recorded.[2] In the first 10 years of fatality reporting, the average diver fatality per year was 123.[2] Approximately half of all recorded recreational scuba fatalities occurred from 1970 through 1979, when both the dive industry and number of divers were smaller.[2] Today, the average number of fatalities is approximately 104 deaths per year,[2] as the number of divers has grown into the millions. In February 1994, PADI alone certified its five millionth diver. These facts reflect the trend that diving safety has improved greatly over the years. The estimated fatality rate, per 100,000 active dives per year, has dropped from about 8.6 in 1976 to about 2.7 in 1991.[1] Figure 1 shows the total numbers of U.S. recreational diving fatalities by year, as reported by NUADC and DAN.[1,2] The incidence of scuba deaths has generally shown a decreasing trend since 1970. Improved training standards, equipment and diver awareness are in part responsible.

Throughout the world, the popularity of scuba is increasing. Fortunately, diving deaths are rare; while this is good news, we must persevere with the fundamental educational issues of diver health and safety. Fewer deaths each year are only possible when we all continue to emphasise the importance of diver training and awareness.

It is important to analyse and review the factors involved in diving fatalities. To help us understand and avoid diving deaths, we need to know more about the divers and what they were doing during the dive. In a general review of the top three causes of diving deaths between 1970 and 1992, drowning/asphyxia was the leading cause, followed by embolism and heart attack/cardiac problems.

Table 1 reflects the primary diving activity at the time of death as reported by DAN.[1,2] Note that 10.4% of the deaths occurred in divers who were under instruction. This is an instructor's nightmare. These sobering data remind all involved in diver training of the importance of good judgment, control and emergency procedures in our dive planning for open water diver training.

Twenty-one deaths occurred in technical diving environments in 1991 and 1992.[1,2] At least 10 of these people were not properly trained or equipped for the dive they chose to do. Several of these technical deaths were diving at depths greater than the recreational limit of 40 m (130 ft), at least five were to depths of 60 m (200 ft) or more.[1,2]

Other fatalities were attributed in part to diving conditions. Environmental conditions vary widely throughout the world with the effects such as latitude, temperature, elevation, wind, current and visibility changing from site to site and even on the same site from one moment to the next. Divers should stay within the limits of their training and skills when choosing a dive site. Furthermore the dive conditions should be consistent with one's training, experience and comfort level.

Death usually results from multiple factors. However, there is often one event or condition which precipitates a sequence of events. While single event problem solving may be routine, multiple problems occurring simultaneously or in sequence may overwhelm a diver.

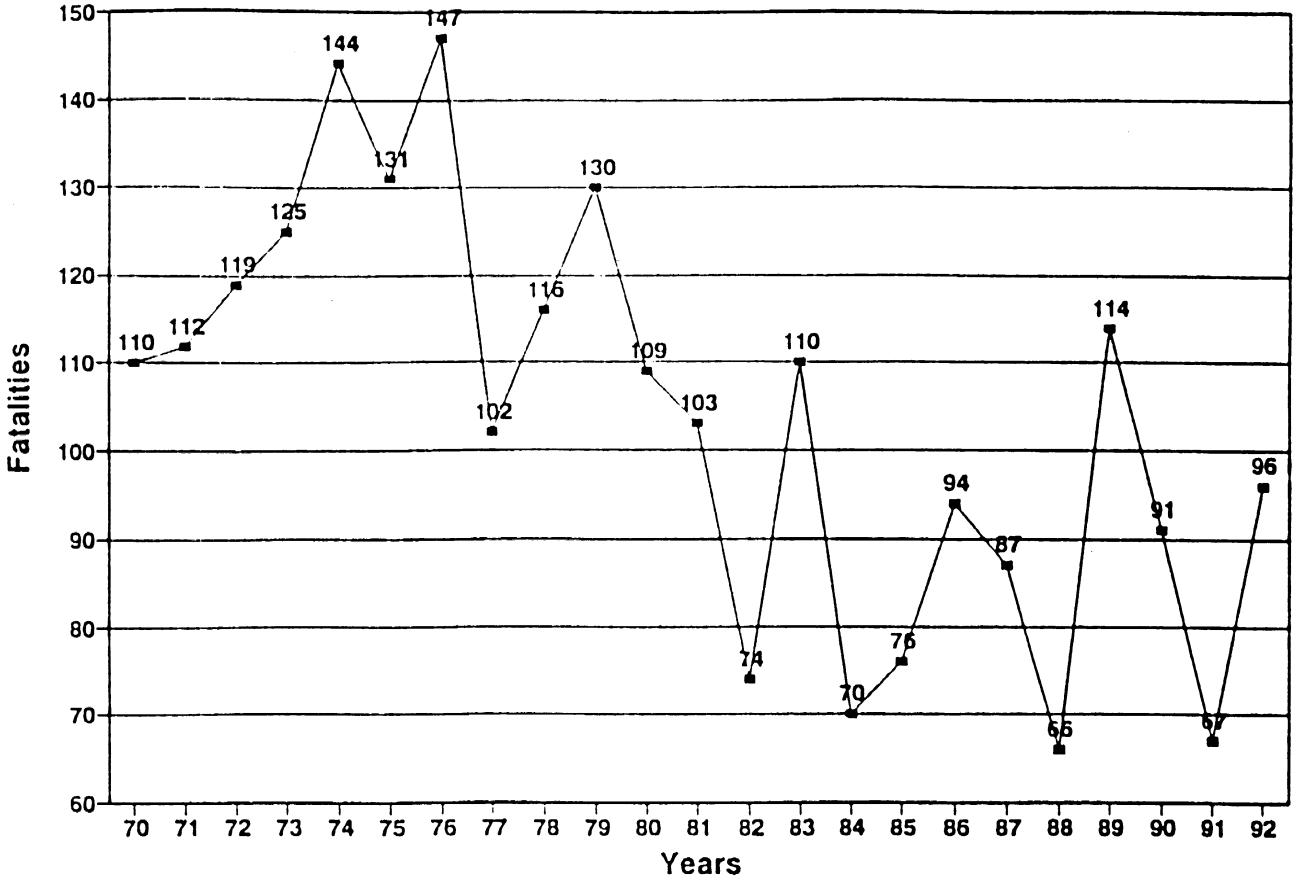

Figure 1. United States recreational diver deaths in the years 1970 to 1972 (Compiled from reference 2).

TABLE 1

DIVE ACTIVITY AT TIME OF DEATH

Dive Activity	Certified to Scuba Dive	Not Certified to Scuba Dive	Certification Unknown	Total	%
Unknown	—	—	5	5	3.0%
Pleasure	63	11	2	76	46.6%
Under instruction	7	10	—	17	10.43%
Spearfishing or hunting	14	1	I	16	9.8%
Wreck diving	15	—	—	15	9.2%
Photography	6	—	—	6	3.6%
Collecting/work/task	4	—	1	5	3.0%
Night	2	—	—	2	1.2%
Non-recreational diving					
Cave	13	—	—	13	79%
Deep more than 39 m (130 feet)	6	—	—	6	3.6%
Under Ice	2	—	—	2	1.2%
TOTAL	**132**	**22**	**9**	**163**	**100.0%**

Table 2 shows when and where the deaths occurred.[1,2] The relatively high number of divers who experienced a problem late in the dive and on the surface after the dive is significant. When one stressful event sets up a chain reaction of events, these events, if unresolved, may lead to death. Examples of events that contributed to deaths are: entrapment, getting lost, running out of air, rapid ascent, panic, narcosis, asthma, cardiovascular

TABLE 2

WHEN AND WHERE THE PROBLEMS OCCURRED IN 155 DIVING DEATHS

	When
Surface Predive	7
Immediately	8
Early Dive	21
Mid-Dive	19
Late Dive	41
Post Dive	33
Unobserved	21
No Information Available	5
	Where
Surface	7
During Descent	15
At Depth	33
During Ascent	39
Surface Post Dive	35
Unobserved	21
No Information Available	5

disease, alcohol and drug use. Table 2 emphasises the need for divers to pay attention to safety during all phases of the dive. Buddy separation was reported in nearly half of the deaths for the period. There were also five divers in 1992 who died while diving alone.

Worthy of special mention is careful air supply monitoring. Air management continues to be of concern. DAN reports that air consumption was the probable starting cause in several deaths. These cases included: running out of air, low on air, insufficient air causing a rapid ascent, running out of air as a secondary event to entrapment or being trapped.

Table 3 identifies the certification level of the 1991 and 1992 fatalities.[1,2] Entry-level divers have skills, experience and knowledge that limit them to diving conditions similar to their training environment. PADI and other training organisations recommend additional training to become familiar with different conditions and environments. Quality entry-level training, continuing education, proper attitude and judgment, environmental orientation diving and adherence to safe diving practices all help.

The causes of death are of interest. Of the cases that were autopsied, it was determined that 22 deaths were due to arterial gas embolism (AGE); 11 were immediate and 11 suffered AGE before drowning.[1,2] The factors that led up to this were insufficient air supply problems, panic, lung abnormality, presumed breath holding, rapid ascent, asthma, coronary artery disease, obesity, sudden death (in a presumably healthy individual), diabetes and buoyancy problems at the surface.

TABLE 3

CERTIFICATION LEVEL OF 163 DEATHS IN 1991/1992

Certification	**Number**	**%**
None	12	7.3
Unknown	15	9.2
Student	10	6.1
Basic/Open Water	80	49.0
Advanced	20	12.2
Rescue	2	1.2
Divemaster	9	5.5
Instructor	7	4.2
Commercial	1	0.6
Military	2	1.2
Cave/Cavern	5	3.0
TOTAL	**163**	**100**

Drowning remains the most frequent cause of death in divers (Table4). It follows the occurrence of factors that prevent the diver from either reaching or remaining on the surface. Many people think that “drowning” as cause of death may simply be the response of non-diving coroners who do not autopsy. Buoyancy problems at the surface, where the diver failed to establish buoyancy and sank were reported in several cases. Panic may complicate the diver’s ability to operate equipment, such as a BCD, properly or to drop a weight system. Insufficient air leading to drowning contributed to 32% of the total drownings reported.[2]

These sobering statistics should renew our personal commitment to diving safety and education. If we understand the risks that have led divers to their deaths, we may be more effective in influencing the attitude and judgement of other divers.

Responsibility to Diving Safety

After certification, ultimate responsibility for safety rests with each diver. The responsible individual must make the decision to dive or not for himself. The role of the diving instructor is to train each person to be capable of assessing diving conditions without help after training. For divers to make this choice, thorough training and teaching are important, as are disciplined diving habits within the buddy team in the field.

Over 15 years ago PADI published the PADI Safe Diving Practices in the PADI *Diver Manual* as follows:[3]

1 Maintain good mental and physical fitness for diving. Avoid being under the influence of alcohol or

TABLE 4

FACTORS CONTRIBUTING TO DROWNING

Contributing Factors	Number of Divers
Insufficient air	41
Buoyancy problem*	15
Entrapment	23
Cardiovascular	12
Alcohol/drugs	9
Panic state	9
Nitrogen narcosis	7
Air embolism	10
Hypothermia	1
Obesity	4
Rapid ascent	4

*At the surface, failed to establish buoyancy and sank.

dangerous drugs when diving. Keep proficient in diving skills, striving to increase them through continuing education and reviewing them in controlled conditions after inactivity.

2 Be familiar with your dive sites. If not, obtain a formal diving orientation from a knowledgeable, local source. If diving conditions are worse than those in which you are experienced, postpone diving or select an alternative site with better conditions. Engage only in diving activities which are consistent with your training and experience.

3 Use complete, well maintained, reliable equipment with which you are familiar; and inspect it for correct fit and function prior to each dive. Deny use of your equipment to uncertified divers. Always have a buoyancy control device and submersible pressure gauge when scuba diving. Recognise the desirability of an alternative source of air and a low pressure buoyancy control inflation system.

4 Listen carefully to dive briefings and directions and respect the advice of those supervising your diving activities.

5 Adhere to the buddy system throughout every dive. Plan dives, including communications, procedures for reuniting in case of separation, and emergency procedures, with your buddy.

6 Be proficient in dive table usage. Make all dives no-decompression dives and allow a margin of safety. Have a means to monitor depth and time under water. Limit maximum depth to your level of training and experience. Ascend at a rate of 18 m (60 ft) per minute.

7 Maintain proper buoyancy. Adjust weighting at the surface for neutral buoyancy with no air in the buoyancy control device. Maintain neutral buoyancy while under water. Be buoyant for surface swimming and resting. Have weights clear for easy removal, and establish buoyancy when in distress while diving.

8 Breathe properly for diving. Never breath-hold or skip-breathe when breathing compressed air, and avoid excessive hyperventilation when breath-hold diving. Avoid overexertion while in and under the water and dive within your limitations.

9 Use a boat, float or other surface support station whenever feasible.

10 Know and obey local diving laws and regulations, including fish and game and dive flag laws.

These guidelines evolved from many years' experience. Safe diving guidelines result from accident history and are adopted in the attempt to help others avoid repeating mistakes. Still in use today, it is possible some new divers may not necessarily know why these guidelines were created or the fact that many resulted from accident and fatality analysis.

In 1993 Edouard Lagache, a doctoral candidate at the University of California, Berkeley, produced a paper titled, *An introduction to semi-qualitative methods for the analysis of recreational scuba accident data*. In it he analysed 10 years of diver fatality data from the Ontario, Canada, Underwater Council 1989 report. He compared the events and circumstances surrounding the fatalities in this report to a list of safety rules he derived from the established PADI Safe Diving Practices. Lagache reported his findings in the Undersea Journal in an article entitled, *Are Divers Choosing to Die ?*[4] He suggested that in 87% of the deaths, at least one derived safety rule was broken and in over 80% of these cases, the violation clearly contributed to the accident! His research supports the commonsense notion that violating safety guidelines does indeed have something to do with promoting accidents. The rules that were broken with the most frequency were, dive with good gear and set up for the chosen location, do not use alcohol or drugs, do not lend gear to uncertified people and groups of divers should be broken down into buddy teams.

Certain violations can be classified as those that cannot be violated without choosing to do so. Lagache's research indicates that in 41 % of all fatality cases he analysed, when rules were broken, they may have been broken by the individual diver's choice and not by accident. Additionally, his data supports the premise that series of chain events (multiple events) are most often involved in diver fatality, ultimately overwhelming the diver and prohibiting any chance of recovery.

Diver training and education programs address the problem of ignorance and inexperience in divers. Diver education has indeed reduced fatalities over the years. Education has limits, however, and individual attitude is an important factor. Because people can do whatever they wish to do, responsible choice making and social peer acceptance variables have an important role and influence at the dive site.

The development of proper attitudes about training is the key to maximising the likelihood that the majority of divers will stick to proven safety guidelines. This process begins in the entry level diver course with the instructor. It is reinforced within the various training materials, texts and industry publications available to divers.

To be successful in reducing diving fatalities, responsible diving behaviour must be nurtured at a grass-roots level. Because diving is a social pursuit, divers do learn from other divers, buddies, friends and divemasters. All of these people collectively provide a community of example. In this way, divers go through a type of apprenticeship. Social forces and peer pressure shape diving practice either in a positive or negative way, depending on what the group tolerates. Good diving habits are developed in part by example and safety attitudes. Divers who rush into the water with leaking regulators or faulty equipment without solving the problem, need to stop and think about the fact that they are increasing the risk to themselves and their partners. Responsible group dynamics must accommodate corrective behaviour, before diving, in order to keep risk levels acceptable.

Ideally, safety is freedom from risk. Unfortunately, risk is unavoidable in any sport and diving is no exception. However, risk can be minimised. Good judgment and training will help ensure risks are judged as acceptable and diving will remain "safe." History has shown the benefits of detailed dive planning, performing a pre-dive safety check and following safe diving practices in reducing diving deaths. Diving death is not a random event. While we may never be able to reduce the fatalities to zero, we must never cease in our efforts to do so.

Bibliography

1 *1991 Report on diving accidents and fatalities*. Durham, North Carolina: Divers Alert Network, 1992
2 *1992 Report on diving accidents and fatalities*. Durham, North Carolina: Divers Alert Network, 1994
3 *Diver Manual* . Santa Ana, California: PADI, 1978
4 Lagache E. Are divers choosing to die? *Undersea Journal* 1993; 4th quarter:

Drew Richardson is Vice-President, Training, Education and Memberships, PADI International Inc., 1251 East Dyer Road, Suite 100, Santa Ana, California 92705-5605, U.S.A.

The address of the Divers Alert Network is Box 3823, Duke Medical Center, Durham, North Carolina 27710, U.S.A.

A PROGRESS REPORT ON DIVING MEDICINE STUDIES IN THE ROYAL NEW ZEALAND NAVY

Des Gorman, Alison Drewry and Simon Mitchell

Abstract

Three prospective, randomised, controlled studies involving oxygen-helium and lignocaine in decompression illness and lignocaine in patients undergoing cardiopulmonary bypass are underway at the Royal New Zealand Navy's Auckland Naval Base. Two other studies are designed to elucidate whether there are objective markers of decompression illness, in either the coagulation cascade or bone imaging; and a survey of the health status of the Royal New Zealand Navy Diving branch has been conducted. No progress has been made in the study of the role of chest and abdominal splinting in the prevention of pulmonary barotrauma.

Introduction

A series of studies relevant to diving medicine have been initiated by researchers at the Auckland Naval Base. These include:

a) prospective, randomised, controlled trials of (i) oxygen-helium versus oxygen, (ii) lignocaine versus placebo in the treatment of decompression illness (DCI) arising from recreational air diving, and (iii) lignocaine versus placebo in the prevention of brain injury due to gas emboli during cardiotomy;

b) a study to determine whether there are any measurable changes in the coagulation system in DCI,

c) a study of bone changes in acute DCI using nuclear magnetic resonance imaging (NMRI);

d) a survey of the current health status of the Royal New Zealand Navy (RNZN) Diving Branch;

e) a study of the role of chest and abdominal splinting in the prevention of pulmonary barotrauma.

These studies are reviewed below: