1991 Report on Diving Accidents & Fatalities

Direct financial support for this report was provided by the National Oceanic and Atmospheric Administration (NOAA) and the Dive Equipment Manufacturers Association (DEMA). DAN also recognizes the dive clubs, stores, instructors, and many individual members who support DAN and diving safety.

Divers Alert Network
Box 3823
Duke University Medical Center
Durham, North Carolina 27710

1991 Report on Diving Accidents and Fatalities

Table of Contents

Acknowledgments

Data for the *1991 Report on Diving Accidents and Fatalities* was collected and assembled by DAN employees and staff. These contributions ranged from accident follow-up calls, data entry, editing, proofreading, and compiling the final report. DAN wishes to recognize the following people for their important contributions:

Peter Bennett Ph.D., D.Sc.
Richard Moon M.D.
G. Yancey Mebane M.D.
Guy de L. Dear M.B., F.R.C.A.
John Rorem B.A.
Jeffery Hodson EMT-D
Richard R. La Reno EMT
Randy Sitzes EMT
Michele Nealen
Sally Reiser B.S.
Philip Trommel B.A., EMT
Barbara Willingham DMT

Joel Dovenbarger R.N., Director of Medical Services - Editor
Karen Corson MPH - Diving Epidemiologist
Natalie Lew B.S. - Fatality Research Specialist
Gary Nichols - Layout and Design

DAN wishes to thank the many hyperbaric physicians, DAN on-call staff, nurses, and technicians from the national network of chambers who fill out DAN reporting forms and send them in for follow-up. DAN also wishes to thank the local sheriff, police, emergency medical personnel, U.S. Coast Guard, medical examiners, and coroners who submitted information on scuba fatalities. Mr. John J. McAniff, of the University of Rhode Island, has joined with DAN to produce the section on recreational and commercial diving fatalities. This report is made possible through NOAA Grant NA26RU0449-01, and through support from the Diving Equipment Manufacturers Association.

DAN Volunteer First Call Resident Physicians
Jim Chimiak M.D.
David N. DuBois M.D.
Mark Hagood M.D.
William T. Jacoby M.D.
Steve Maxfield M.D.
Michael L. Maynor M.D.
Mike Webb M.D.
Stephanie Young M.D.

DAN Senior Staff Physicians
Guy de L. Dear M.B., F.R.C.A.
Thomas A. Fawcett M.D.
Philip J. Fracica M.D.
G. Yancey Mebane M.D.
Richard Moon M.D.
Claude A. Piantadosi M.D.
Bret Stolp M.D., Ph.D.

Regional Coordinators

Southeast Region and Headquarters
Alabama, Florida, Georgia, North Carolina, South Carolina, Tennessee, Caribbean Basin
Peter Bennett Ph.D., D.Sc., National Director
Richard Moon M.D., Medical Director
F.G. Hall Hyperbaric Center
Box 3823
Duke University Medical Center
Durham, North Carolina 27710

Northeast Region
Connecticut, Maine, Maryland, New Hampshire, New York, Pennsylvania, Virginia
Roy Myers M.D. and Paul Rodier
Department of Hyperbaric Medicine
Maryland Institute for
Emergency Medical Services Systems
University of Maryland
22 S. Greene Street
Baltimore, Maryland 21201

Northwest Region
Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Wisconsin
Robert Goldmann M.D. and Stephen Fabus
Department of Hyperbaric Medicine
St. Luke's Medical Center
2900 W. Oklahoma Avenue
Milwaukee, Wisconsin 53215

Pacific Region
Hawaii
Frank Farm
Hyperbaric Treatment Center
University of Hawaii
John A. Burns School of Medicine
42 Ahui Street
Honolulu, Hawaii 96813

Southwest Region
Arizona, California, Utah
Paul Linaweaver M.D. and
Hugh Greer M.D.
Santa Barbara Medical Foundation
Clinic
Department of Preventive/
Occupational Medicine
P.O. Box 1200
Santa Barbara, California 93102

Gulf Region
Arkansas, Colorado, Louisiana, Mississippi, New Mexico, Oklahoma, Texas, Mexico
Keith Van Meter M.D.,
and Sheldon Gottlieb Ph.D.
Department of Hyperbaric Medicine
Jo Ellen Smith Medical Center
4400 General Meyer Avenue
New Orleans, Louisiana 70131

Midwest Region
Alaska, Montana, Oregon, Washington
Richard Dunford M.S.
Hyperbaric Department
Virginia Mason Research Center
952 Seneca Street
Seattle, Washington 98111

Divers Alert Network

Divers Alert Network (DAN) is the United States' safety organization for recreational scuba diving. DAN is a 501(c)3 not-for-profit company that relies on dues from its membership to support DAN services and scuba diving safety research. The membership of DAN includes individual divers, dive clubs, retail scuba operators, equipment manufacturers, scuba certification agencies and special individuals who donate their services, time and money to support diving safety.

Scuba diving like most other recreational sports has a potential for personal injury. Breathing compressed gas underwater creates a certain amount of risk. DAN's mission is to enhance diving safety for recreational divers by helping them to avoid injury and provide assistance when injuries occur. DAN supports this mission by:

1. Providing information on health/safety issues in scuba diving to the general public and physicians.
2. Providing emergency assistance for the evaluation, transportation and treatment of injured divers.
3. Collecting, analyzing and publishing data on diving accidents and fatalities.

DAN is now the largest diving safety organization in the world, with approximately 95,000 individual and family members. DAN has recently organized the first international federation of diving safety organizations. The goals are to provide worldwide assistance for information, air evacuation and acceptance of insurance programs. Similar organizations now exist with the same mission under International DAN (IDAN) such as DAN Europe, DAN Japan, and DAN Australia.

Divers Alert Network is best known in the diving community for its medical emergency and advisory telephone services to recreational divers and physicians.

• ***24-Hour Medical Emergency Hotline (919) 684-8111)*** — DAN maintains a 24-hour emergency service 365 days a year to provide injured divers with medical consultations and referrals.

• ***Non-Emergency Advisory Line (919) 684-2948)*** — DAN maintains an information hotline to provide answers for commonly asked questions about scuba diving medicine and safety. Calls are answered 9 a.m. to 5 p.m., EST, Monday through Friday, except holidays.

These telephone services are totally supported by membership dollars and are provided free to all callers. The combined telephone services handle over 12,000 calls annually.

Alert Diver — Alert Diver is the bimonthly magazine of Divers Alert Network sent to each DAN member. ***Alert Diver*** provides the latest in diving medicine and safety information.

Diving Safety Courses — DAN provides courses for divers, instructors and physicians who wish to increase their awareness and understanding of scuba diving injuries and treatment. Many divers attend DAN's one-day courses, and over 1,500 physicians have been introduced to diving medicine through DAN's one-week seminars. The DAN *Oxygen First Aid in Dive Accidents* program trained

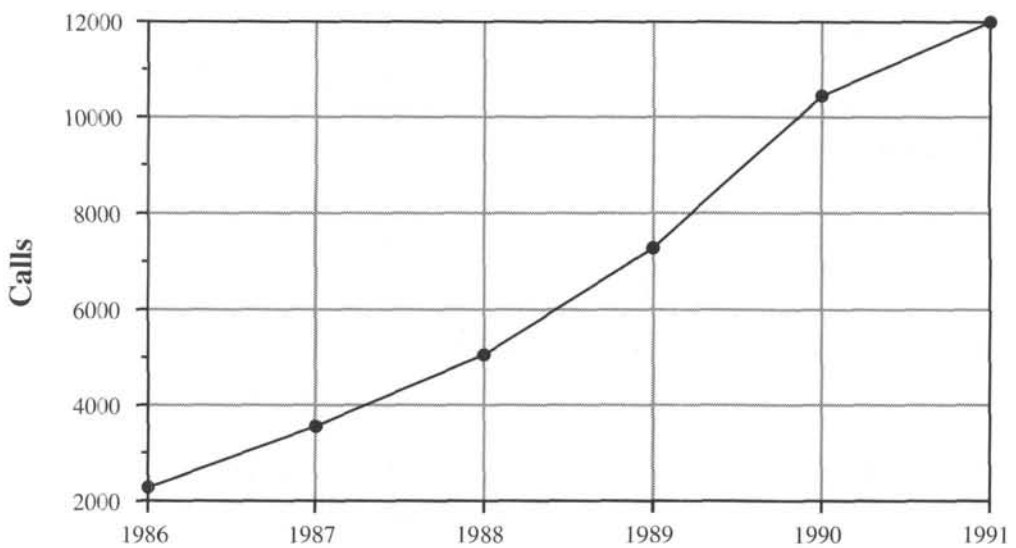
1,850 oxygen providers and 280 instructors in the first year it was offered. DAN has now trained over 5000 providers, 600 instructors, and 30 oxygen instructor trainers worldwide.

Accident Insurance — DAN pioneered and implemented the first diving injury insurance for recreational divers in the United States. For those who choose this benefit, payment for emergency treatment is assured. DAN members are covered anywhere in the world for all in-water injuries.

Annual Report on Scuba Diving Accidents— DAN collects the details of recreational dive injuries and fatalities. This data is analyzed for common injury trends and divided into descriptive and possible risk attributes.

Worldwide Air Evacuation Assistance— Regular membership now includes guaranteed worldwide coverage for air evacuation. All DAN members are guaranteed medical evacuation from anywhere in the world for any medical emergency through the **DAN Assist America Plan** if they are more than 100 miles from home. There is no additional cost to the DAN members for this service.

Emergency and Information Combined Telephone Call Volume



1.0 Introduction to Dive Accidents

This is the fifth annual report on recreational scuba accidents and the third to include scuba fatalities. DAN receives reports from over 130 treatment facilities in the United States, Caribbean Basin Islands and the Pacific territories. DAN is also in contact with physicians and chamber staff worldwide who assist in tracking American scuba injuries. Not all divers with decompression symptoms get evaluated and treated so the actual number of cases is probably higher.

The true incidence of injury in recreational scuba diving cannot be established. The precise number of active divers cannot be obtained at present. For example, new scuba trainees each year can only be estimated. Once certified, divers may not actually dive each year. Because of such variables, attempts to find the risk of injury must be estimated.

Injuries are an expected outcome in contact sports such as football and soccer which have an estimated incidence of 2.86 percent to 1.28 percent. Although there are far fewer deaths and catastrophic injuries (paralysis) in these sports, these events do occur. There are also many types of permanent injuries, such as musculoskeletal problems. It is difficult to compare the type of injury in one sport to another because some sports injuries could be much more severe than others.

Scuba diving differs not only in the type of injury that may occur, but also in the surrounding physical environment. Because scuba is different from contact and land based sports, a brief comparison is made to other water-oriented activities. Scuba differs from all other recreational activities because it requires that the individual carry their own source of breathing air. This implies an inherent risk.

There is a perception that scuba diving is more dangerous than other water sports, but the *estimated incidence* of injury and death is lower for scuba than swimming or water skiing. Using information provided by the National Safety Council, water skiing, swimming, and scuba are compared. The National Electronic Injury Surveillance System (NEISS) surveys 90 emergency departments nationwide to obtain an estimate of reported injuries per activity. The National Sporting Goods Association (NSGA) surveys 20,000 households to estimate the number of activity participants. There may be bias in the reporting of these numbers, and there is no guarantee that the bias is evenly distributed among the activities. The 1991 estimates show a 0.03 percent increase in estimated incidence of injury for scuba. This was due in large part to the participant estimate being decreased by 600,000 by the NSGA. The estimated incidence for water skiing and swimming also increased. Using estimates provided by the National Underwater Accident Data Center (NUADC) at the University of Rhode Island, the estimated incidence of injury for scuba is no greater than 0.04 to 0.05 percent.

Table 1.1 Estimated Occurrence of Injuries in Water-Related Activities

Sport	Estimated Participants	1991 Reported Injuries	Estimated Incidence
Scuba	2,000,000	1,400	0.07%
Swimming	67,500,000	115,112	0.17%
Water Skiing	10,500,000	25,128	0.24%

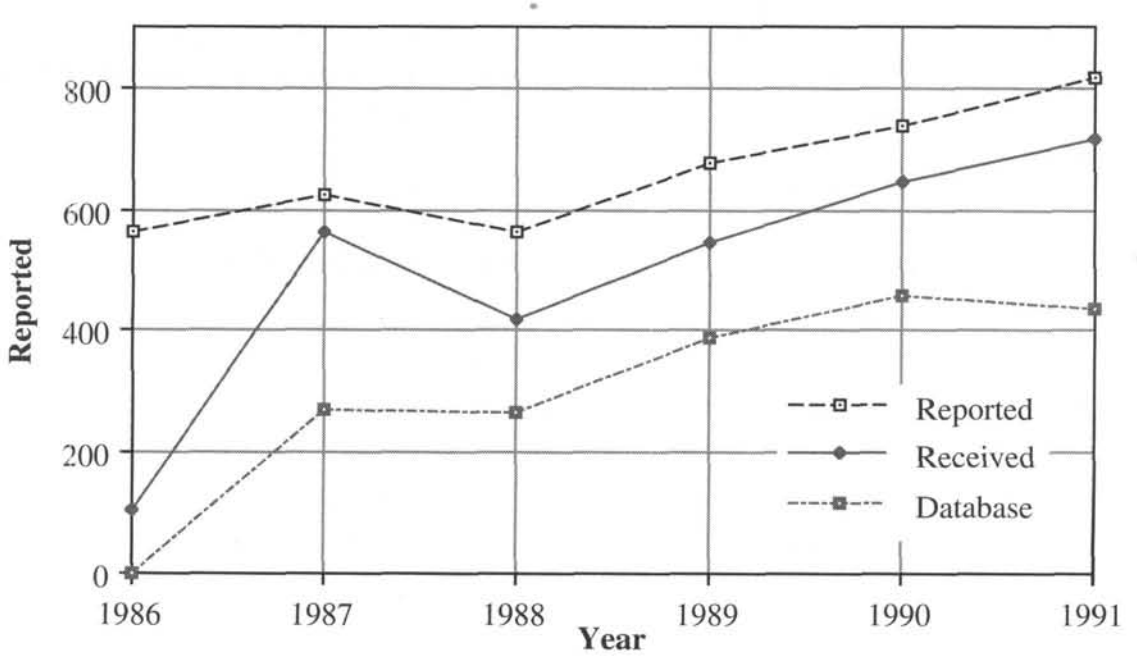
By Sept. 1, 1992, DAN had received 708 DAN Diving Accident Reporting Forms. Of these, 437 forms were followed and included in the DAN computer database. Eighty-one cases were excluded from analysis because they were performing commercial dives. One hundred and ninety cases were excluded because they were not traceable, in litigation, or not considered decompression illness (i.e., marine life envenomization, ear squeeze, etc.).

The 437 cases included were based upon the diagnosis being decompression illness and the case reports being complete and verified. There were some cases that may have had one or two missing answers on the form which the diver could not recall. Cases missing a few responses were included because the major portion of information was available and considered useful. In these cases the denominator was reduced to show that not all cases in the data base were used to calculate this percentage, thus, it would not give an exaggerated total number for that question. Because of this, "*Frequency Missing*" may be seen throughout the report to indicate that a response was not given. In some places "*n=x*" denotes the size of the population to which a table or graph refers.

In many tables there were very few respondents to certain questions which led to a small number divided by a large number resulting in a very small percentage (i.e., 0.036 percent). When calculated, the computer rounds up (or down) to the nearest tenth or the nearest hundredth. It is because of rounding that some percentages do not total 100 percent exactly.

Some hyperbaric chambers do not send report forms to DAN. Other chambers give the patient the form to send in, and often these forms are not received. The number of cases reported by the different DAN regions is always higher than the number of forms received at DAN, as can be seen in Graph 1.2. The dotted top line indicates total cases reported by DAN regions. The middle solid line indicates total cases received by DAN, and the bottom dashed line represents total cases completed and verified which are included in DAN's accident database. DAN has been able to report on between 43 percent to 62 percent since starting the annual report. The 1991 report represents 54 percent of the total number of divers who were treated.

Graph 1.2 Decompression Illness Cases from 1986-1990



DAN collects cases from network hyperbaric chambers and persons who have experienced decompression illness. DAN also receives reports from members who were at the site of an accident and who later have the victim fill out a report. Once a case is received which fits the appropriate criteria (recreational scuba, decompression related), it is then logged into the DAN database. If a patient has residual symptoms, he or she is contacted by telephone and followed until they no longer have residual symptoms or for up to three months if they continue to have residual symptoms. If a patient has no residual symptoms, he or she is contacted by telephone only if there is incomplete or incongruent information on the reporting form.

The Dan Diving Accident Reporting Form used to collect accident information is presented in Appendix A. The names and identifying personal information are confidential and are not available for publication. Accident data cannot be used to imply individual fault or blame in determining the cause of scuba injuries.

Case Collection

Divers Alert Network utilizes a regional system of accident reporting. Each region has a coordinator who assists in the triage and treatment of divers in their region. They also assist in the collection of cases from the hyperbaric chambers. The increased and improved collection efforts by DAN are due to the cooperation of the many hyperbaric facilities in the referral network and to the regional coordinators. Comparisons may be made from year to year, by region, or by diagnosis. The apparent increase in the number of treated injuries is due in part to DAN's efforts in collecting cases. The increase in cases is also supported by the increasing call volume to DAN and the number of physician referrals for evaluation. It also reflects higher numbers of non-decompression illness related injuries and non-recreational injuries. The present collection system has been in place for six years and has continued to increase in efficiency and effective reporting.

Some divers are treated at two or three different facilities, but they are only counted as one dive accident. Divers can only be counted twice if there were two separate episodes of decompression illness. Chambers in the region may have reported more cases of decompression illness, but Table 1.3 represents only cases of recreational decompression illness.

Table 1.3 shows the number of decompression illness cases reported being treated over the last five years. The total number of treated cases has been slowly increasing since 1986 with the exception of 1988 when the number of cases declined. Regions in Table 1.3 refer to certain states and areas of the country. States are listed by region in Table 1.4. The Caribbean basin islands are shown separately but are part of the southeast region.

Tables 1.5 and 1.6 show the location of diving for the 437 reported cases in 1991. Foreign hyperbaric treatment chambers assist DAN by collecting accident reporting forms on all local diving. Non-U.S. citizens and commercial divers are excluded from data base cases but are included in cases received. Table 1.5 and 1.6 show the location of the dives that led to symptoms but do not necessarily indicate the site of treatment.

810 809 437

Table 1.3 Total Reported Cases of Decompression Illness

1991	SW	NW	MW	GU	PA+	NE	SE**	TOTALS
DCS-I	34	12	6	32	*	40	109	233
DCS-II	83	21	21	22	1	49	240	437
AGE	26	2	8	9	*	6	36	87
No DX reported					57			57
No Treatment++	1				1		4	6
TOTALS	**144**	**35**	**35**	**63**	**59**	**95**	**389**	**820***
1990								
DCS-I	31	8	17	31		28	111	243
DCS-II	60	8	10	37		34	193	346
AGE	13	1	2	7		15	58	118
No DX reported					31			31
No Treatment++								
TOTALS	**104**	**17**	**29**	**75**	**31**	**77**	**362**	**695***
1989								
DCS-I	48	12	18	11		14	78	181
DCS-II	64	15	17	29		47	156	328
AGE	35	3	3	1		4	65	111
No DX reported					58			58
No Treatment++								
TOTALS	**147**	**30**	**38**	**41**	**58**	**65**	**299**	**678**
1988								
DCS-I	14	9	11	13		22	68	137
DCS-II	43	27	10	25		32	151	288
AGE	25	6	2	1		10	38	82
DCS-AGE combined	1			4			5	10
No DX reported					36			36
No Treatment++		3		1	1	2	5	12
TOTALS	**83**	**45**	**23**	**44**	**37**	**66**	**267**	**565**
1987								
DCS-I	15	4	2	15		30	61	127
DCS-II	58*	25	12	20		26	199	340*
AGE	20	4	2	6		6	59	97
No DX reported					38			38
No Treatment++	2					3	17	22
TOTALS	**95**	**33**	**16**	**41**	**38**	**65**	**336**	**624**
1986								
DCS-I		6	2	1			68	77
DCS-II	69*	11	13	8	7	33	133	274*
AGE	28	2				10	41	81
No DX reported					25		97	122
No Treatment++	3					1	4	8
TOTALS	**100**	**19**	**15**	**9**	**32**	**44**	**343**	**562**

* *Represents DCS Types I and II cases combined.*

** *SE includes Caribbean basin.*

\+ *Hawaii only reports number of cases treated.*

++ *No Treatment represents cases with no treatment, refused treatment, or spontaneous resolution.*

Table 1.4 Total Cases Reported Treated in 1991 by Region

Southwest Region	DCS-I	DCS-II	AGE	TOTALS
Arizona	0	4	0	4
California	33	78	25	136
Utah	1	1	1	3
TOTALS	**34**	**83**	**26**	**143**

Northwest Region				
Oregon	3	1	0	4
Washington	9	20	2	31
TOTALS	**12**	**21**	**2**	**35**

Midwest Region	DCS-I	DCS-II	AGE	TOTALS
Illinois	1	6	3	10
Indiana	0	1	2	3
Iowa	1	0	0	1
Kentucky	0	1	0	1
Michigan	1	3	0	4
Minnesota	1	6	3	10
Ohio	2	2	0	4
Wisconsin	0	2	0	2
TOTALS	**6**	**21**	**8**	**35**

Gulf Region	DCS-I	DCS-II	AGE	TOTALS
Colorado	4	4	1	9
Louisiana	7	5	4	16
Mississippi	1	0	0	1
Missouri	1	0	0	1
New Mexico	6	0	1	7
Oklahoma	0	2	0	2
Texas	13	9	2	24
TOTALS	**32**	**22**	**9**	**63**

Pacific Region	DCS-I	DCS-II	AGE	TOTALS
Hawaii				57*
Guam	0	1	0	1
TOTALS				**58***

Northeast Region	DCS-I	DCS-II	AGE	TOTALS
Connecticut	6	2	0	8
Maine	0	9	1	10
Maryland	17	1	0	18
New York	5	28	3	36
Pennsylvania	12	8	2	22
Virginia	0	1	0	1
TOTALS	**40**	**49**	**6**	**95**

Southeast Region	DCS-I	DCS-II	AGE	TOTALS
Alabama	4	3	0	7
Florida	75	108	17	200
Georgia	4	0	1	5
North Carolina	2	9	1	12
South Carolina	2	3	0	5
Tennessee	2	0	0	2
TOTALS	**89**	**143**	**19**	**251**

Caribbean	DCS-I	DCS-II	AGE	TOTALS
Bahamas	2	10	3	15
Barbados	1	3	0	4
Belize	1	1	0	2
Bermuda	0	2	0	2
Bonaire	0	5	0	5
Cayman	7	12	2	21
Honduras	*	13	2	15
Jamaica	0	2	1	3
Mexico	9	25	7	41
Puerto Rico	0	3	2	5
Saba	0	3	0	3
St. Thomas	*	13	0	13
Turks & Caicos	0	5	0	5
TOTALS	**20**	**97**	**17**	**134**

**The categories DCS-I and DCS-I were combined.*

Table 1.5 1991 Accidents by Country and U.S. Territory

Country	Frequency	Percentage
Indonesia	1	0.2
Fiji	1	0.2
Thailand	1	0.2
Truk	2	0.5
British Virgin Islands	2	0.5
Jamaica	2	0.5
Cocos Island	2	0.5
British West Indies	3	0.7
Canada	3	0.7
Antilles	3	0.7
Other	3	0.7
Bonaire	4	0.9
Turks and Caicos	7	1.6
Belize	7	1.6
Honduras	11	2.5
U.S. Territories	12	2.7
Caymans	20	4.6
Bahamas	29	6.6
Mexico	35	8.0
USA	288	65.9
TOTAL	**436**	**100.0**

Frequency Missing = 1

Table 1.6 1991 Accidents by State and U.S. Territory

State	Frequency	Percent
Delaware	1	0.3
Idaho	1	0.3
Indiana	1	0.3
Maryland	1	0.3
Nevada	1	0.3
South Carolina	1	0.3
Utah	1	0.3
Missouri	2	0.7
Ohio	2	0.7
Alabama	3	1.0
Louisiana	3	1.0
Michigan	3	1.0
Wisconsin	3	1.0
Puerto Rico (U.S.)	3	1.0
Massachusetts	4	1.3
New Mexico	4	1.3
Minnesota	5	1.7
Rhode Island	5	1.7
New York	6	2.0
Texas	6	2.0
Hawaii	8	2.7
U.S. Virgin Islands	9	3.0
New Jersey	10	3.3
North Carolina	20	6.7
Washington	23	7.7
California	30	10.0
Florida	144	48.0
TOTAL	**300**	**99.9**

Frequency Missing = 137

2.0 Injured Diver Characteristics

The 1991 diver age distribution is very similar to data from previous years (Table 2.1). The most noticeable difference is the decrease of accidents in the 20-29 year age group which continues a downward trend since 1988. Another shift is the increase in the 10-14 age category. The six divers in this age range who were injured in 1991 equal the total number reported for the four years, 1987-1990. Junior open water certification limits divers to 60 feet of diving or less; however, two of the divers were diving deeper than 60ft. Five divers were certified and one was a student. One had been diving for two years, the remaining five had been diving one year or less. Three of these cases were DCS I, involving pain-only symptoms, the other three were DCS II of which one case was possibly AGE. Five of the cases were treated within 12 hours and received one treatment; the sixth case waited until the next day to seek treatment and had neurological symptoms until retreated. There were no residual symptoms in any of the divers.

Table 2.1 Age Distribution of Accident Cases From 1987 to 1991

Age	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
10-14	6	1.4	0.2	0.3	0.7	0.7
15-19	12	2.8	3.3	2.8	1.5	4.1
20-24	34	7.8	9.0	8.2	10.1	10.4
25-29	70	16.1	22.9	24.0	23.1	19.3
30-34	103	23.7	22.5	22.0	23.9	23.3
35-39	98	22.3	20.5	14.6	14.6	22.2
40-44	55	12.6	11.8	12.3	13.1	11.9
45-49	34	7.8	5.0	7.4	7.1	4.1
50-54	13	3.0	3.1	4.3	4.1	1.1
55-59	6	1.4	1.1	2.8	0.7	1.1
60-64	5	1.1	0.7	1.3	1.1	1.9
TOTALS	**436**	**100.0**	**100.1**	**100.0**	**100.0**	**100.0**
Frequency Missing = 1			*n* = 458	*n* = 391	*n* = 268	*n* = 270

Table 2.2 illustrates the age ranges by sex of the divers and the severity of the injury. The DAN Severity Coding System (Appendix C) is used to code the severity of injury. A severity code of "1" represents pain in the arms and legs only. A higher severity code (2 to 6) represents a more serious injury and a more complex presentation of symptoms and symptom locations. A severity code of "6" could represent paralysis, convulsions, or a state of altered consciousness.

Table 2.2 1991 Disease Severity by Age and Sex

MALE

Age	SEVERITY 1	2	3	4	5	6	TOTALS
10-14	2	1	1	0	0	0	4
15-19	0	1	4	5	0	2	12
20-24	3	6	1	7	5	4	26
25-29	7	4	3	18	15	4	51
30-34	11	14	8	13	21	6	73
35-39	10	20	4	21	16	5	76
40-44	5	6	4	11	11	5	42
45-49	3	5	1	7	7	2	25
50-54	2	2	0	1	4	1	10
55-59	1	0	0	1	1	1	4
60-64	0	0	0	2	0	2	4
TOTALS	**44**	**59**	**26**	**86**	**80**	**32**	**327**

FEMALE

AGE	SEVERITY 1	2	3	4	5	6	TOTALS
10-14	0	0	0	0	1	1	2
15-19	0	0	0	0	0	0	0
20-24	1	3	0	4	0	0	8
25-29	3	2	3	6	4	1	19
30-34	2	3	1	14	10	0	30
35-39	1	2	3	8	6	2	22
40-44	0	1	2	4	3	3	13
45-49	1	0	1	3	4	0	9
50-54	0	1	0	2	0	0	3
55-59	0	1	0	0	1	0	2
60-64	0	0	0	1	0	0	1
TOTALS	**8**	**13**	**10**	**42**	**29**	**7**	**109**

Frequency Missing = 1

Table 2.3 Sex of 1987-1991 Accident Cases

Sex	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Female	110	25.2	26.4	26.1	21.6	24.1
Male	327	74.8	73.6	73.9	78.4	75.9
TOTAL	**437**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
		$n = 437$	$n = 459$	$n = 391$	$n = 268$	$n = 270$

Approximately 27 percent of the scuba diving population has been reported as female (DAN prospective study 1989). This is about the same as the percentage of females in the injury statistics, supporting the notion that females are neither more nor less likely than males to experience decompression illness.

Table 2.4 Number of Divers by Years of Diving Experience

Years Diving	Sex	1991	1990	1989	1988	1987
< 2 Years	Male	93	81	37	35	56
	Female	50	55	21	25	29
2 to 5 Years	Male	104	106	79	62	46
	Female	41	44	32	17	14
6 to 9 Years	Male	27	55	36	37	31
	Female	7	8	9	12	14
≥ 10 Years	Male	103	96	98	76	72
	Female	12	14	8	3	8

The percentage of females suffering a diving injury with five years of diving experience was 82 percent in 1991. There was no change from 1990. Forty-five percent of the female injuries occurred in the first two years of diving compared to 21 percent of the total male injuries. Diver experience is broken down in Table 2.5 by total years of diving and reported number of dives. A number of variables could influence when injuries occur such as style of diving, frequency of diving and level of training. The males appear to be evenly distributed by years of diving experience. The exceptions being first year divers and those males with 4 to 5 years of diving experience and more than 120 dives shown in Table 2.5.

Table 2.5 Diver Experience

MALE

Years Diving	Total Dives 0-20	21-40	41-60	61-80	81-100	100-120	121+	TOTALS
0-1	64	11	5	3	3	0	7	93
2-3	10	15	11	13	2	3	17	71
4-5	4	0	6	2	2	0	19	33
6-7	0	2	1	2	1	0	9	15
8-9	2	0	1	0	0	1	8	12
10-11	2	1	1	0	0	1	13	18
12-13	1	2	3	1	3	1	4	15
14-15	0	2	0	0	0	0	11	13
16-17	0	1	1	0	1	0	8	11
18-19	0	0	0	0	0	0	6	6
20-21	2	1	0	0	0	0	37	40
TOTALS	**85**	**35**	**29**	**21**	**12**	**3**	**139**	**327**

FEMALE

Years Diving	Total Dives 0-20	21-40	41-60	61-80	81-100	100-120	121+	TOTALS
0-1	27	13	6	3	0	0	1	50
2-3	8	7	2	2	2	0	4	25
4-5	0	0	3	1	3	1	8	16
6-7	0	0	0	0	0	0	2	2
8-9	0	0	1	0	0	0	4	5
10-11	0	0	0	0	0	0	3	3
12-13	0	0	0	0	0	0	1	1
14-15	1	0	0	0	0	0	1	2
16-17	0	0	0	0	0	0	1	1
18-19	0	0	0	0	0	0	0	0
20-21	1	0	0	0	0	0	4	5
TOTALS	**37**	**20**	**12**	**6**	**5**	**1**	**29**	**110**

Table 2.6 Certification Level of 1987-1991 Accident Cases

Certification	Male	Female	Totals	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Student	7	6	13	3.0	0.7	3.1		
Basic	21	5	26	5.9	10.0	7.7	13.4	15.6
Open Water	137	51	188	43.0	44.0	41.4	35.4	35.9
Advanced	77	25	102	23.3	20.9	27.9	26.9	22.2
Divemaster	30	10	40	9.2	6.8	6.1	4.9	5.6
Instructor	40	11	51	11.7	10.5	10.5	11.2	11.1
Commercial	0	0	0	0.0	0.9	0.3	4.1	
Other	8	2	10	2.3	4.6	1.5	3.0	1.1
None	7	0	7	1.6	1.5			4.1
Unknown	0	0	0	0.0	0.2	1.5	1.1	4.4
TOTALS	**327**	**110**	**437**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

1991 had about the same number of injured students as 1989. The reason for the sharp decrease in 1990 is unclear. The years 1987 and 1988 did not have the "student" option and thus students were reported under "none" or "open water" depending on where they were in the certification process.

For the first time since computerizing the database in 1987, there were no unknown certification levels. This report does not include any divers who were diving commercially with the exception of instructors, who may be considered commercial but are an integral part of the recreational dive community. Except for a possible downward trend in the percentage of basic divers and a slightly upward trend in the percentage of divemasters, there have been no consistent differences from year to year in any category.

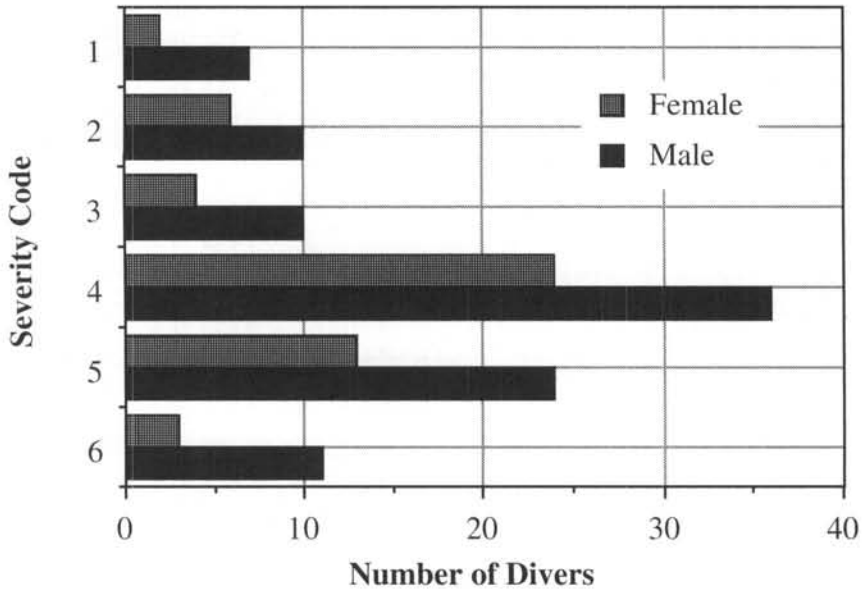
Table 2.7 New Diver Profile Attributes

Traits	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent
Outside Limits	31	20.4	23.8	18.0	31.0
Rapid Ascent	64	38.1	38.1	43.0	41.0
Square Dives	99	60.4	50.8	51.0	61.0
Diving ≥ 80 fsw	102	58.9	64.6	46.0	61.0
Repeat Dive	95	56.2	64.6	59.0	50.0
≤ 20 Dives	117	70.9	76.8	72.0	75.0
		n = 169	*n* = 181	*n* = 114	*n* = 78

Frequency Missing = 268

New divers are defined by DAN as those who have not done more than 20 dives or have less than two years experience. New divers as a separate group were not studied until 1988. Twenty-nine to thirty-nine percent of the yearly injuries have been new divers.

Graph 2.8 New Divers with Less than Two Years of Experience for 1988-1990



A high percentage of new divers appears to be in the more seriously injured group compared to the rest of the injury population.

Table 2.9 shows the distribution by severity code of individuals with a current medical problem. Compared to 1990, there are no significant changes within the severity codes.

Table 2.9 Current Medical History and Disease Severity Code of Decompression Illness for 1991

	Severity						
Problem	**1**	**2**	**3**	**4**	**5**	**6**	**TOTALS**
Chest-lung	0	3	3	7	2	1	16
Asthma	1	1	0	2	0	1	5
Chest-heart	1	0	0	0	1	0	2
GI/Abdomen	0	1	0	5	4	1	11
Brain	0	0	0	0	0	0	0
Spine/Back	0	3	2	8	5	3	21
Limb/Joint DCS	1	0	0	1	0	0	2
Circulation/Blood	0	0	0	0	1	2	3
Neuro/Nerv system	0	2	0	0	2	1	5
Muscl/Skel system	2	3	2	4	3	2	16
Eye	0	0	0	1	0	0	1
Mental/Emotional	0	1	1	4	0	2	8
Other	0	9	4	13	12	4	42
None	47	49	26	89	82	26	319
TOTALS	**52**	**72**	**38**	**134**	**112**	**43**	**451***

Frequency Missing = 3

** Divers may have had more than one current problem*

Table 2.10 Percentage of Divers Without Current Health Problems

Current	1991	1990	1989	1988	1987
Frequency	319	342	282	180	174
Percent	74%	80%	72%	67%	64%
	n= 434	*n*= 426	*n*= 391	*n*= 268	*n*= 270

Twenty-six percent of all injured divers in 1991 (Table 2.10) listed a current medical problem, an increase of six percent from 1990.

Table 2.11 Previous Illness and Disease Severity Code of Decompression Illness for 1991

	Severity						
Problem	**1**	**2**	**3**	**4**	**5**	**6**	**TOTALS**
Chest-lung	0	2	1	7	4	4	18
Asthma	2	3	0	3	2	4	14
Chest-heart	0	3	1	2	2	0	8
GI/Abdomen	2	5	3	11	16	5	42
Brain	0	0	1	1	0	0	2
Spine/Back	3	9	4	19	14	2	51
Limb/Joint DCS	7	5	4	12	9	6	43
Circulation/Blood	2	0	1	1	1	0	5
Neuro/Nerv system	0	3	2	2	4	2	13
Muscl/Skel system	11	11	4	18	9	6	59
Eye	1	0	0	6	1	0	8
Mental/Emotional	0	1	1	2	2	1	7
Other	9	8	3	17	19	5	61
None	24	38	19	59	46	15	201
TOTALS	**61**	**88**	**44**	**160**	**129**	**50**	**532***

** Divers may have had more than one illness.*

Table 2.11 shows people reporting a previous illness. The percentage of persons in severity codes 1 and 2 reporting previous illness has increased slightly while the percentage of persons with previous illness in the severity code 4-5 has decreased slightly from 1990.

Table 2.12 Percentage of Divers Without Past Health Problems

Past Illness	1991	1990	1989	1988	1987
Frequency	201	219	184	129	131
Percent	46%	48%	47%	48%	48%
	n= 437	*n*= 458	*n*= 391	*n* = 268	*n*= 270

Fifty-four percent (Table 2.12) of those in the 1991 accident database reported having at least one previous illness. This is not significantly different from the 52 percent reported in 1990.

Table 2.13 Physical Fitness of Accident Cases

	1991		1990		1989		1988	
Sex	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Male	297	90.8%	299	88.5%	270	93.4%	184	87.6%
Female	99	90.0%	105	86.8%	90	90.0%	49	84.5%
TOTAL	**396**	**90.6%**	**404**	**88.0%**	**360**	**92.5%**	**233**	**86.9%**
	n = 437		*n* = 459		*n* = 389		*n* = 268	

Table 2.13 shows the respondents who answered "Yes" to the question, "Are you physically fit?" This is self-reported. The data indicate fitness does not prevent accidents.

A high percentage of divers felt they were physically fit at the time they had decompression illness. Seventy-two percent stated that they exercised on a weekly basis, averaging 3.5 days a week per diver.

Table 2.14 Strenuous Exercise Before, During or After Dive in 1991

Sex	Before Dive	During Dive	After Dive
Male	73	208	24
Female	18	61	10
TOTAL	**91**	**269**	**34**

Additionally, many individuals chose to perform strenuous activity prior to their dive and sometimes after their dive on the same day. Strenuous activity is subjective for each diver and does not mean the activity exceeded the ability of the diver to perform that activity. Exercise to the point of muscle fatigue is suspected to contribute to the development of decompression illness and should be avoided from one to six hours before and after diving.

Table 2.15 Medication Use of the 1988-1991 Accident Cases

1991			
Prescription Use		Non-prescription Use	
Frequency	Percent	Frequency	Percent
100	22.9%	85	19.5%
$n = 437$		$n = 435$	

1990			
Prescription Use		Non-prescription Use	
Frequency	Percent	Frequency	Percent
132	30%	66	18.7%
$n = 440$		$n = 353$	

1989			
Prescription Use		Non-prescription Use	
Frequency	Percent	Frequency	Percent
93	24.9%	25	7.7%
$n = 374$		$n = 325$	

1988			
Prescription Use		Non-prescription Use	
Frequency	Percent	Frequency	Percent
58	21.9%	71	27.2%
$n = 265$		$n = 261$	

The percentage of divers using prescription medication has not increased over the last four years. This is not an unexpected result since more than half of all divers have some past health illness (Table 2.11) which may be chronic and require medication. The "$n =$" represents the number of people who responded to these questions.

Table 2.16 Percentage of Alcohol Use in 1988-1991 Accident Cases

Time of Use	1991	1990	1989	1988
Night before	36.6	39.9	40.9	43.3
Pre-dive	2.3	8.7	1.8	1.5
Between dives	1.8	1.1	1.9	2.2
Post-dive	14.2	16.1	15.6	10.4
None	56.3	53.6	48.3	51.9
	$n = 437$	$n = 457$	$n = 391$	$n = 268$

** Some divers engage in drinking in more than one category.*

Alcohol consumption is believed to contribute to decompression illness because of its tendency to cause dehydration due to diuresis. The exact role alcohol plays in decompression illness is unknown. Alcohol consumption can lead to an altered state of personality and impaired judgment. Perhaps the most significant aspect of alcohol use in diving is its dehydrating effect. Without appropriate rehydration fluids, repetitive post-dive drinking for several days may lessen the body's ability to offgas nitrogen accumulated during scuba diving. Performance may be impaired for many hours after being intoxicated.

Table 2.17 Alcohol Use Up to 12 Hours Before Diving in 1991

	Number of Drinks							
Severity	**1**	**2**	**3**	**4**	**5**	**6**	**≥7**	**TOTAL**
1	3	5	6	3	1	0	0	18
2	2	9	6	1	3	1	1	23
3	1	3	1	2	0	0	3	10
4	15	14	12	2	2	3	3	51
5	10	15	3	4	3	5	5	45
6	1	7	2	4	2	0	0	16
TOTAL	**32**	**53**	**30**	**16**	**11**	**9**	**12**	**163**

Frequency Missing = 1
Who did not drink = 273

Table 2.17 shows the severity of injury in individuals who drank prior to their dive. These 163 divers consumed a total of 521 drinks.

Table 2.18 Nausea, Hangover, Diarrhea, and Recreational Drug Use

Sex	Nausea	Hangover	Diarrhea	Drug Use
Male	8	8	7	4
Female	5	3	4	2
TOTALS	**13**	**11**	**11**	**6**

Frequency Missing = 1

Table 2.18 shows acute conditions that occurred during the dive trip prior to injury. Nausea and diarrhea have been the most common acute conditions affecting the diver on the dive day for the past several years. Vomiting and diarrhea may contribute to diver dehydration and physical disability. These conditions occur in only a minority of cases and may only contribute to a small number of all cases.

Table 2.19 Lack of Sleep and/or Fatigue Prior to Last Dive

Sex	1991 Percent	1990 Percent	1989 Percent	1988 Percent
Male	34.5	24.9	30.1	32.9
Female	30.9	33.9	39.4	27.6
TOTALS	**33.6**	**27.2**	**32.5**	**31.7**
	n = 437	*n* = 459	*n* = 385	*n* = 268

Fatigue and lack of sleep can impede optimal physical performance and lead to inappropriate decision making. Fatigue is also a symptom of decompression sickness. According to the data shown in Table 2.19, 33.6 percent of the 1991 injury population began the dive-injury day fatigued or with less than an adequate amount of sleep.

Smoking History

The 1991 database had a slight increase in the percent of people who listed that they had smoked in the past and also in those who reported that they had never smoked. None of these findings were statistically significant. The percentage of current smokers in scuba diving continues to fall below the national average as reported in the 1988 National Health Interview Survey by the Center for Disease Control. According to the 1988 survey, 51.9 percent of the U.S. population were either current or past smokers. The injured diver population has ranged between 30.6 and 43.1 percent. Twenty-eight percent of the national population currently smoke, while only 15 percent of the DAN injury population were current smokers. A 1989 random survey of DAN Prepared Members found that 13 percent were current smokers, and 44 percent had smoked in the past. A relationship has not been established between smoking and cerebral gas embolisms. In order to examine a possible relationship between smoke-induced lung disease and AGE, diagnosis versus smoking history was evaluated. Twenty-four percent of current smokers had a gas embolism, but 64 percent of these individuals had a contributory rapid ascent or buoyancy problem (29 percent). The remainder of the current smokers (76 percent) were diagnosed with decompression sickness and 20 percent of those individuals had a rapid ascent. The percentage of AGE is higher among the current smokers group than in the entire population; but the percentage of contributory factors was also higher. No conclusion can be made that smokers are at a higher risk for AGE than non-smokers, based on current data.

Table 2.20 Smoking History of 1988-1991 Accident Cases

Smoke	1991 Percent	1990 Percent	1989 Percent	1988 Percent
Present	15.1	16.3	15.3	13.1
In past	27.7	26.8	24.8	17.5
Never	57.2	56.9	59.8	68.7
TOTALS	**100.0**	**100.0**	**100.0**	**99.3**
	n = 437	*n* = 455	*n* = 391	*n* = 268

3.0 Dive Profile

The dive profile section is composed of tables and charts which demonstrate the type of underwater activity being performed, as well as various attributes of the dives when a diving incident occurred. Data from three previous years is presented in many of the tables to show whether changes in the pattern of diving have taken place. Dive profile information should only be considered in relation to the various attributes.

The vast majority of divers suffer their injuries while sightseeing. Wreck diving and spearfishing were the next two most common activities of those injured (Graph 3.1). Most sport scuba diving is done in salt water, and this is probably the reason for the greater number of accidents in that environment (Table 3.2).

The majority of injuries occurred within a month of the last safe dive made by that particular diver (235 divers or 56 percent). This would seem to indicate that most divers in the accident database are frequent participants. There were, however, a large number of divers in whom the accident dive was the first dive for over a month. This group includes both the frequent divers, experienced divers and new trainees (Graph 3.3).

Graph 3.1 Primary Dive Activity When Injury Occurred

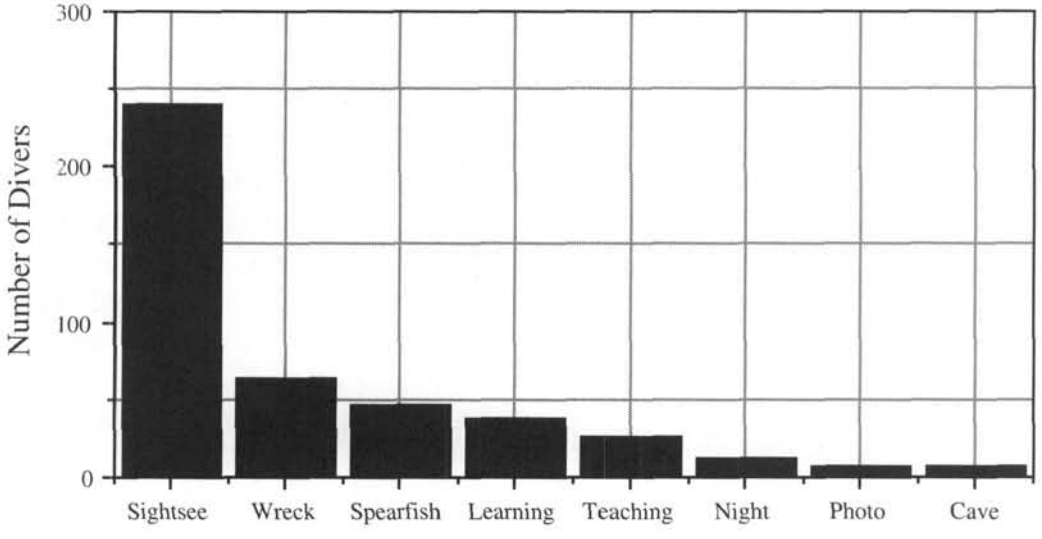
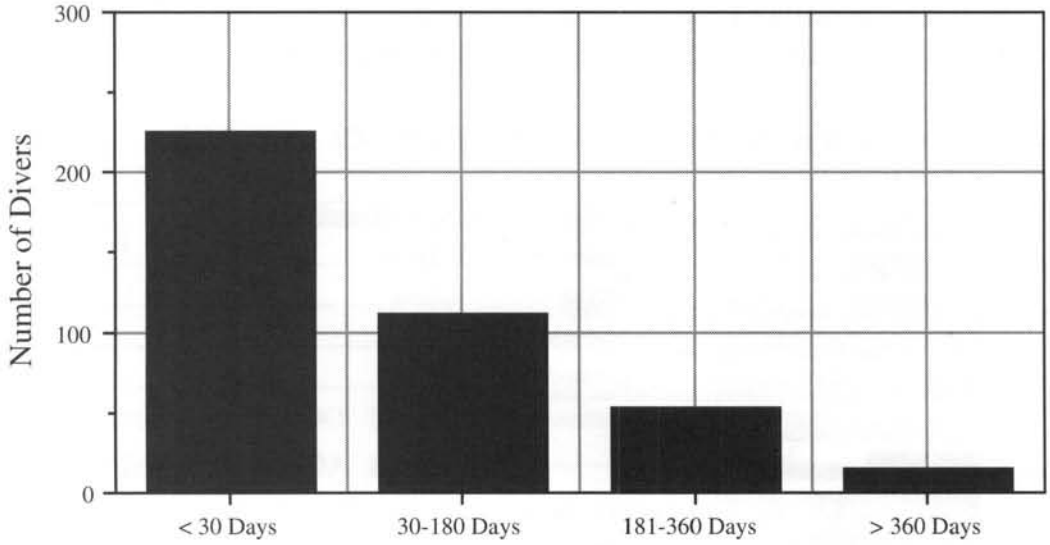


Table 3.2 Type of Water Environment

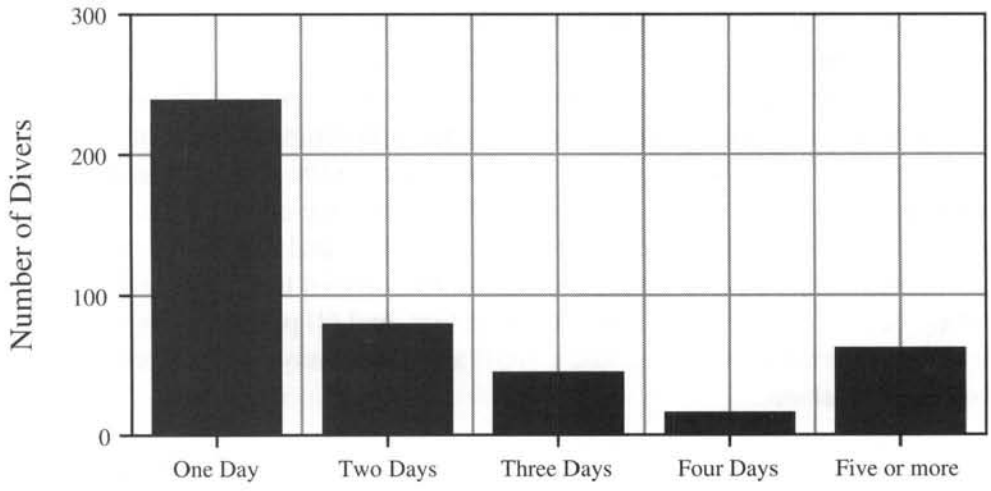
Type	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent
Freshwater	52	11.9	12.9	12.5	15.0
Saltwater	385	88.1	87.1	87.5	85.0
TOTAL	**437**	**100.0**	**100.0**	**100.0**	**100.0**
		n = 437	*n* = 458	*n* = 391	*n* = 267

Graph 3.3 Days Since Last Safe Dive



Fifty-four percent of divers were injured on a single day diving program compared to 48 percent of the combined repetitive day divers (Graph 3.4). The incidence of accidents in persons making single day dives in the accident population has remained about the same over the last four years (see Table 3.6 and 3.7).

Graph 3.4 Number of Days Diving

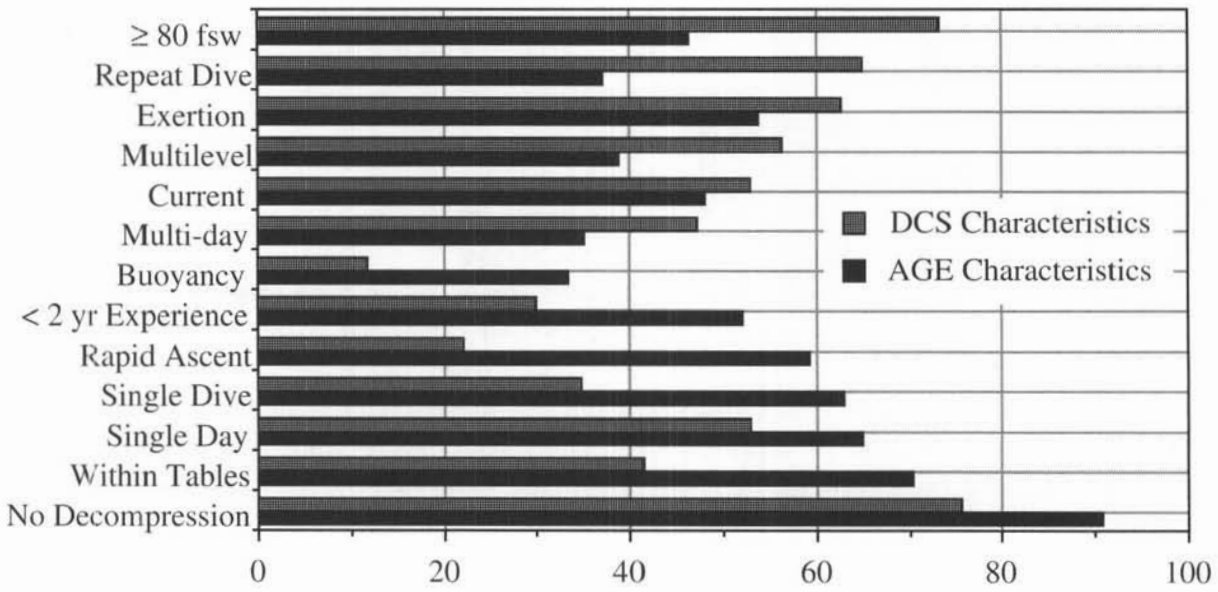


Dive Characteristics

The characteristics of dives which resulted in both types of decompression illness: decompression sickness (DCS), and arterial gas embolism (AGE), were similar (Graph 3.5). Gas embolism can occur in any diver who ascends too rapidly from any depth. This is as a result of excessive pressure in the lungs or a failure of expanding lung gases to escape from the diver caused by air trapping or breathholding. DCS results from the duration of exposure at a depth of around 30 feet or greater. Both conditions cause bubble formation which can produce symptoms in the individual.

The data on the two types of decompression illness are reported separately because the proposed mechanism of injury is different. The characteristics of the dives which produce each injury are approximately the same, but the frequency of occurrence is different. The characteristics of each diagnosis from previous years are also presented to demonstrate yearly trends.

Graph 3.5 Characteristics of Dives that Resulted in DCS and AGE



The typical AGE incident occurs with no decompression diving, within dive table limits, or during the first dive of the first day. There has been a resurgence of inexperienced divers suffering from AGE, with 52 percent in 1991 compared with 34 percent in 1990. Only 60 percent of divers claim to have made a rapid ascent, which is usually recognized as being the predominant cause of AGE. The characteristics of dives which resulted in AGE have been consistent over the last four years. Table 3.6 shows the comparative yearly data. In divers with AGE, the percentage of divers with rapid ascent has increased over the years from 46 percent to 59 percent. Time and depth exposures are not considered to be a major contributing factor to AGE, and this is reflected in the characteristics presented here. Only 46 percent of divers went deeper than 80 feet, and 60 percent were within the no decompression limit tables. However, the diagnoses, AGE and DCS, may have, in part, been assigned using dive profile information.

A comparison of Tables 3.6 and 3.7 will show various dive characteristics in both AGE and DCS. For example, in 1991 a rapid ascent occurred in 59 percent of AGE cases but only 22 percent of DCS cases.

The characteristics of DCS cases are different from those who reported AGE. DCS was associated with deep dives (80 feet or greater), repetitive diving within the tables and with multi-level profiles. The set of characteristics relating to DCS cases may reflect the number of divers who use dive computers rather than relying on the standard non-decompression tables.

Table 3.6 Characteristics of Dives that Resulted in AGE

Attribute	Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
No Decompression	49	90.7	90.8	92.2	97.8	88.5
Within Tables	38	70.4	80.3	84.8	87.0	78.8
Single Day	35	64.8	66.7	53.8	69.6	88.5
Single Dive	34	63.0	74.6	67.3	71.7	
Square	32	59.3	60.7	60.4	84.8	90.4
Rapid Ascent	32	59.3	57.1	55.8	54.3	46.2
Exertion	29	53.7	22.5	15.7	21.7	21.2
< 2 yr. Experience	28	51.9	33.8	47.1	54.3	38.5
Current	26	48.1	40.0	40.4	30.4	26.9
≥ 80 fsw	25	46.3	52.1	46.2	45.7	51.9
Multilevel	21	40.7	39.3	39.6	15.2	9.6
Repeat Dive	20	37.0	25.4	32.7	28.3	25.0
Multi-day	19	35.2	33.3	46.2	30.4	11.5
Buoyancy	18	33.3	23.9	9.6	28.3	26.9
Fatigue	9	16.7	11.3	25.5	28.3	34.6
		$n = 54$	$n = 71$	$n = 52$	$n = 46$	$n = 52$

Table 3.7 Characteristics of Dives that Resulted in DCS

Attribute	Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
No Decompression	290	75.7	78.9	78.2	70.3	70.6
≥ 80 fsw	281	73.4	76.8	68.2	72.1	68.3
Repeat Dive	249	65.0	81.7	68.5	65.3	63.1
Exertion	240	62.7	24.7	29.4	24.8	35.3
Multilevel	216	56.4	54.6	52.1	45.5	29.0
Single Day	203	53.0	52.9	50.6	48.2	61.9
Current	203	53.0	49.7	42.1	39.2	39.9
Multi-day	180	47.0	47.1	49.4	51.8	38.1
Square	167	43.6	41.2	42.6	54.5	71.1
Within Tables	158	41.3	45.4	54.1	58.1	58.3
Fatigue	138	36.0	30.2	32.9	32.4	37.6
Single Dive	133	34.7	18.3	31.5	34.7	36.9
< 2 yr Experience	115	30.0	28.9	11.5	23.9	29.8
Rapid Ascent	85	22.2	22.4	25.3	23.9	23.4
Buoyancy	45	11.7	9.8	15.3	11.7	12.8
		$n = 383$	$n = 388$	$n = 339$	$n = 222$	$n = 218$

Table 3.8 Decompression Illness in Computer and Table Divers

	Computers					Tables				
	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
DCS I	20.1	28.1	31.0	31.0	26.8	16.0	17.2	18.5	18.5	15.8
DCS II	73.4	64.0	62.7	60.7	61.0	66.8	61.3	64.9	60.3	63.6
AGE	6.5	7.9	6.3	8.3	12.2	17.2	21.5	16.6	21.2	20.6
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
	$n = 199$	$n = 203$	$n = 126$	$n = 84$	$n = 41$	$n = 238$	$n = 256$	$n = 256$	$n = 184$	$n = 228$

The common scenario for AGE is a rapid or panic ascent from the relatively shallow depth at the end of the dive. The interesting fact regarding decompression illness and the rate of frequency of DCS I and DCS II in computer and table divers is that contrary to popular belief, neurological decompression illness was much more common in both groups of divers (Table 3.8). The computer credits the diver for spending time at shallow depths and assumes that nitrogen offgassing occurs at that time. This means that compared with table users, computer users can stay down longer, and make earlier repetitive and deeper dives. When making multi-level dives, computer users can go deeper during their repetitive dives.

In 1991, the trend in the percentage and number of divers using tables, who suffered AGE, remained the same. Arterial gas embolism was approximately two to three times greater in frequency in table users than computer users. The number of divers who suffered pain-only bends (DCS I) was approximately equal in both computer and table users. This was also the case for neurological or more serious bends (DCS II). The reason AGE was more common in table users may be that, in general, computer users were more experienced divers, who have been diving both more often and longer than table users. This may indicate that table users were more likely to miscalculate time and run out of air. The fact that nearly 3/4 of the computer users who suffered decompression illness had neurological signs results from the type of dive that was performed.

Comparison of the trends in those divers who have used either standard decompression tables or dive computers can be made using Tables 3.9 and 3.10. The use of computers supposedly enables divers to make repetitive dives more safely. However, while using computers, over 80 percent of the divers suffering decompression illness in 1991, made multi-level, repetitive dives at depths greater than 80 feet. Other factors such as multi-day diving and fatigue appear less important. It is interesting to note that approximately 25 percent of computer divers thought they were within the tables. However, only 15 percent reckoned they were diving outside the standard decompression table limits, as can be seen in Table 3.11. Stage decompression has further decreased recently in computer users, presumably as the computer indicates there is no need for decompression at the end of the dive schedule. Slightly less than 50 percent of divers with a decompression illness used computers in 1991.

Table 3.9 Attributes of Computer Divers from 1987-1991

Attribute	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Repeat Dive	174	87.4	82.3	73.0	80.5	73.2
≥ 80 fsw	160	80.4	85.7	81.0	82.0	92.7
Multilevel	160	80.4	67.5	68.3	58.4	56.1
Exertion	113	56.8	29.6	31.0	26.2	34.1
Single Day	108	54.3	51.7	48.4	45.5	48.3
Current	94	47.2	52.2	44.4	42.9	43.9
Multi-day	91	45.7	47.8	51.6	54.5	51.7
Decompression	50	25.1	27.1	20.6	36.9	48.8
Within Tables	49	24.6	27.6	26.2	44.0	29.3
		$n = 199$	$n = 203$	$n = 126$	$n = 84$	$n = 41$

Table 3.10 Attributes of Table Divers From 1987-1991

Attribute	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Repeat Dive	169	71.0	70.3	58.5	57.0	52.4
Exertion	156	65.5	23.4	26.0	23.4	32.3
Within Tables	147	61.8	69.1	71.7	71.7	68.1
≥ 80 fsw	146	61.3	62.9	38.5	69.0	60.3
Current	135	56.7	44.9	40.8	35.3	37.9
Single Day	130	54.6	54.3	51.7	52.0	49.7
Multi-day	108	45.4	43.8	48.3	47.6	50.3
Multilevel	87	36.6	39.5	40.8	38.6	19.7
Decompression	43	18.1	12.1	16.2	19.6	21.8
		$n = 238$	$n = 256$	$n = 265$	$n = 184$	$n = 229$

Graph 3.11 1991 Comparison of Computer and Table Diver Attributes

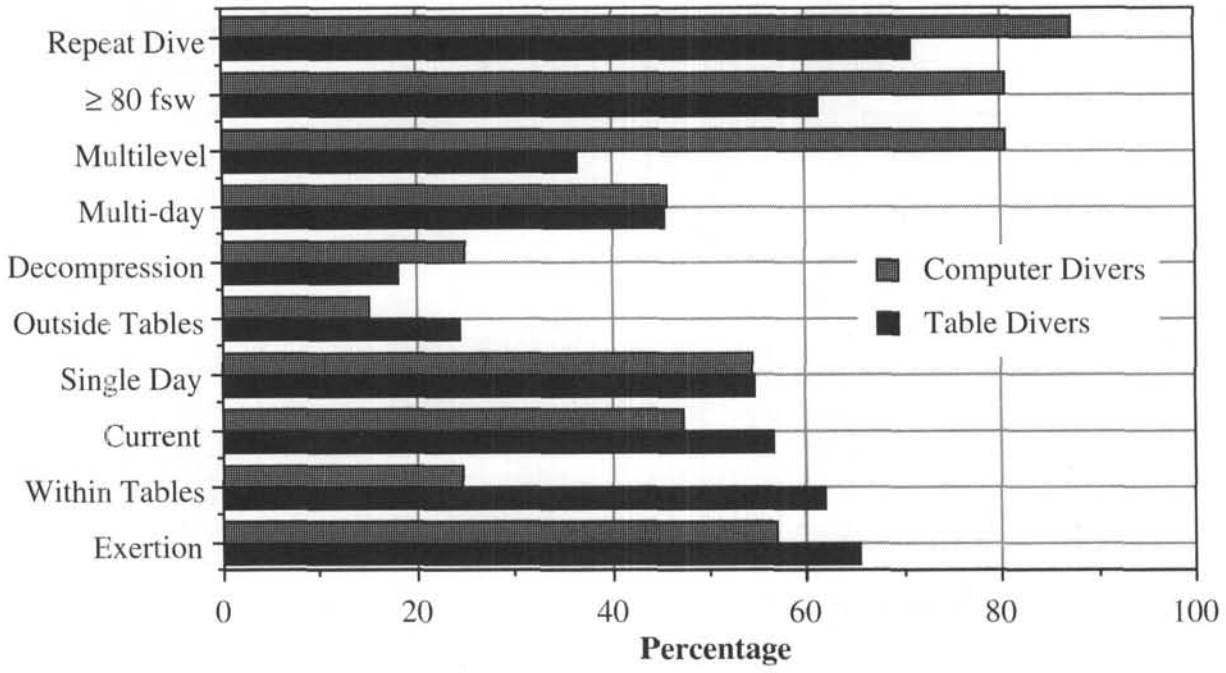


Table 3.12 1991 Equipment Problems

Equipment	Frequency	DCS	AGE
Regulator	10	8	2
BC Vest	7	5	2
Weight Belt	6	5	1
Dry Suit	5	4	1
DC Computer	8	8	0
Inflator Hose	6	6	0
Contaminated Air	1	0	1
Unfamiliar Equip.	13	9	4
Other	10	6	4
TOTALS	**66**	**51**	**15**

Frequency Missing = 371

Scuba diving is an activity that requires knowledge of the equipment used, as well as adequate maintenance. The correct functioning of the equipment and the knowledge of how to use it are essential to diver safety. Fifteen percent of the 1991 cases in this report involved equipment problems. This low number of equipment problems has remained fairly static over the last 5 years Table 3.12).

The fact that equipment problems were reported does not necessarily mean that the equipment failed or malfunctioned. Unfamiliarity with the equipment is also a possible cause for a report to be made. These problems could have been a contributing factor to the development of decompression illness and, in the cases of divers suffering AGE, may have indeed caused the injury. The number of divers reporting equipment problems with AGE, however, was so low that no real conclusions can be drawn from the data.

Those divers with DCS who reported an equipment problem were equally likely to have had a problem with their regulator, dive computer or buoyancy control. The "other" category includes four gauge or timer problems, an improper wet suit fit, a mask leak, a tank not turned on, and three cases where someone else's actions or equipment reportedly led to an injury.

The fact that so few equipment problems were reported may indicate that equipment is actually being used and maintained correctly. Another explanation might be that accident victims are underreporting equipment malfunction.

4.0 Symptoms

Table 4.1 1991 Most Frequent Symptoms of Decompression Illness

Symptom	First Symptom		Total Occurrence	
	Frequency	Percent	Frequency	Percent
Pain	181	41.4	276	63.2
Numbness	83	19.0	234	53.6
Headache	36	8.2	105	24.0
Extreme fatigue	29	6.6	100	22.8
Dizziness	25	5.7	101	23.1
Weakness	22	5.0	114	26.1
Nausea	10	2.3	62	14.2
Difficult breathing	8	1.8	40	9.2
Other	8	1.8	32	7.3
Itching	7	1.6	19	4.3
Unconscious	6	1.4	19	4.3
Personality change	5	1.1	23	5.3
< skin sensation	3	0.7	4	0.9
Rash	3	0.7	13	3.0
Visual disturbance	3	0.7	33	7.6
Restlessness	2	0.5	18	4.1
Speech disturbance	2	0.5	11	2.5
Difficult walking	2	0.5	59	13.5
Semi-conscious	2	0.5	17	3.9
Bladder problem	0	0.0	12	2.7
Hearing loss	0	0.0	5	1.1
Convulsion	0	0.0	1	0.2
Muscle twitch	0	0.0	15	3.4
Ringing ears	0	0.0	7	1.6
Reflex change	0	0.0	4	0.9
Hemoptysis	0	0.0	2	0.5
Bowel problem	0	0.0	11	2.5
Paralysis	0	0.0	26	5.9
TOTALS	**437**	**99.3**		

The frequency of symptoms in decompression illness is shown in Table 4.1. The most common first-presenting symptom in the 1991 accident population was pain. Pain may have been joint, muscular or segmental in nature. The total occurrence of symptoms are also shown for the 1991 injury population. Up to six symptoms may be reported by any individual diver with onset times relating to their first appearance. The fact that numbness and pain appeared in more than 50 percent of all dives in the database is a further corroboration of the neurological nature of most decompres-

sion illness in this population. Any symptoms below the top six listed were relatively uncommon. There are two symptoms that reflect the serious nature of progressive neurological decompression illness. These were the 13.5 percent of divers having difficulty walking at some time after their dive, and the six percent who suffered paralysis.

Table 4.2 Decompression Illness Symptoms Prior to Last Dive

Sex	1991 Frequency		1991 Total	1991 Percent	1990 Percent	1989 Percent	1988 Percent
Male	55	of	327	16.8	13.9	12.4	14.8
Female	27	of	110	24.5	19.0	25.3	26.6
TOTAL	**82**	**of**	**437**	**18.8**	**15.2**	**15.7**	**17.5**
				n = 437	*n* = 459	*n* = 381	*n* = 268

Table 4.2 shows that nearly 19 percent of divers continued diving after the first symptoms of decompression illness appeared. This is presumably due to either a lack of knowledge or an unwillingness to admit to the first symptoms of decompression illness.

Table 4.3 Conventional Disease Diagnosis

Final Diagnosis	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
DCS I	78	17.8	22.0	22.5	22.4	17.4
DCS II	305	69.8	62.5	64.5	60.4	63.3
Air Embolism	54	12.4	15.5	13.0	17.2	19.3
TOTAL	**437**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
			n = 459	*n* = 391	*n* = 268	*n* = 270

The decision to make a diagnosis of DCS I, DCS II or AGE was made either by the treating physician or DAN staff after careful review of all records. The diagnosis of DCS I includes all cases of pain-only bends occurring in extremities that also includes skin bends. DCS II includes all cases with neurological or cardiopulmonary symptoms except those diagnosed as air embolism. The diagnosis of arterial gas embolism was made in those individuals who had an acute onset of neurological symptoms usually within 30 minutes of surfacing (rapid ascent, breathholding, or lung disease), or if the depth-time profile was such that no significant inert gas loading was likely to have occurred. The record for previous years shows the majority of reported cases were neurological decompression illness (DCS II). The percentage of DCS II appears to be rising annually. This incidence in sport divers is different from those reported in professional or military divers. Possible reasons may be:

1) Recreational divers often dive in areas that do not have a hyperbaric chamber which is immediately available. Cases of decompression illness that may have been classified as Type I initially, may progress to Type II because of delay in treatment. Support for this theory is found in Table 4.1 which indicates that the most common first symptom of decompression illness in the DAN database is pain. Subsequent symptoms are often neurological in nature.

2) In professional or military diving, Type II DCS has a greater penalty in terms of time-off work or potential disqualification than Type I, and is often underreported.

3) The changes in the 1991 diagnosis division may reflect the increasing number of computer users in the injury population where the percentage of Type II DCS is increasing and the percentage of AGE is smaller.

Table 4.4 DAN Disease Severity Code

Severity Code	1991 Frequency	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Code 1	52	11.90	11.76	12.00	14.55	11.48
Code 2	72	16.48	15.47	11.80	12.31	20.74
Code 3	36	8.24	6.54	6.40	10.82	9.63
Code 4	129	29.52	32.68	36.10	28.73	30.37
Code 5	109	24.94	25.05	22.00	24.63	15.19
Code 6	39	8.92	8.50	11.80	8.96	12.59
TOTAL	**437**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
			n = 459	*n* = 391	*n* = 268	*n* = 270

The symptoms which are coded 1-6 in the DAN Severity Code are shown in Appendix C. Table 4.4 shows that the majority of symptoms over the years have been more severe symptoms. Code 6, though uncommon, is reserved for the most severe symptoms relating to loss of consciousness and convulsions.

Table 4.5 Percentage of Divers Who Suffered Previous Decompression Illness

Sex	1991	1990	1989	1988
Male	15.9%	12.7%	15.1%	12.4%
Female	3.6%	10.7%	11.8%	8.6%
Total Population	12.8%	12.2%	14.1%	11.6%
	n = 436	*n* = 459	*n* = 391	*n* = 268

Table 4.5 shows that about 13 percent of divers have suffered a previous decompression illness. Females reported fewer second cases of decompression illness. It is unknown how many divers stop scuba diving after an injury. It is obvious from Table 4.5 that some divers do get decompression illness more than once, but it is not clear if this represents a refusal to change dive habits, or if it represents an increased susceptibility to decompression illness.

Table 4.6 Current Injury Severity Code vs. Previous Injury Diagnosis

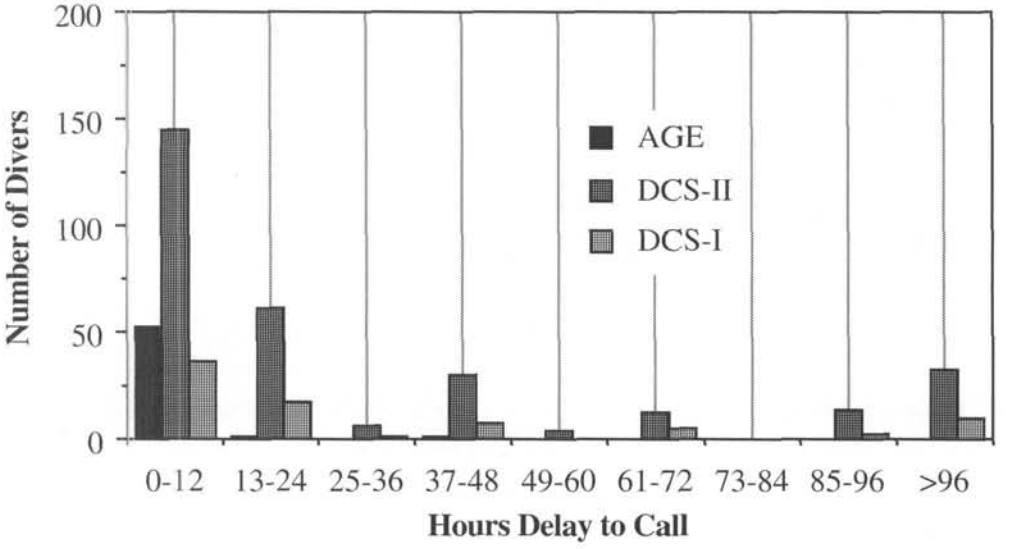
Current Severity	Previous		
	AGE	DCS	Total
Code 1	0	11	11
Code 2	0	7	7
Code 3	0	4	4
Code 4	0	14	14
Code 5	0	12	12
Code 6	2	5	7
TOTAL	**2**	**53**	**55**

Table 4.6 shows previous injuries suffered by divers as either AGE or DCS with the totals for each injury shown at the bottom. The severity of new decompression illness is represented by the severity codes. As might be expected from previous discussions, those who had a previous DCS incident had more severe new decompression illness.

The result of a prospective study performed in 1989 indicated that only 2.5 percent of randomly selected, insured DAN members suffered a previous episode of decompression illness. This may be either as a result of physiological factors or behavioral patterns. These behavior patterns include severe depth-time profiles, repeated diving exposure, or inappropriately high ascent rates. The connection between these behavioral patterns and the incidence of decompression illness has not been fully determined.

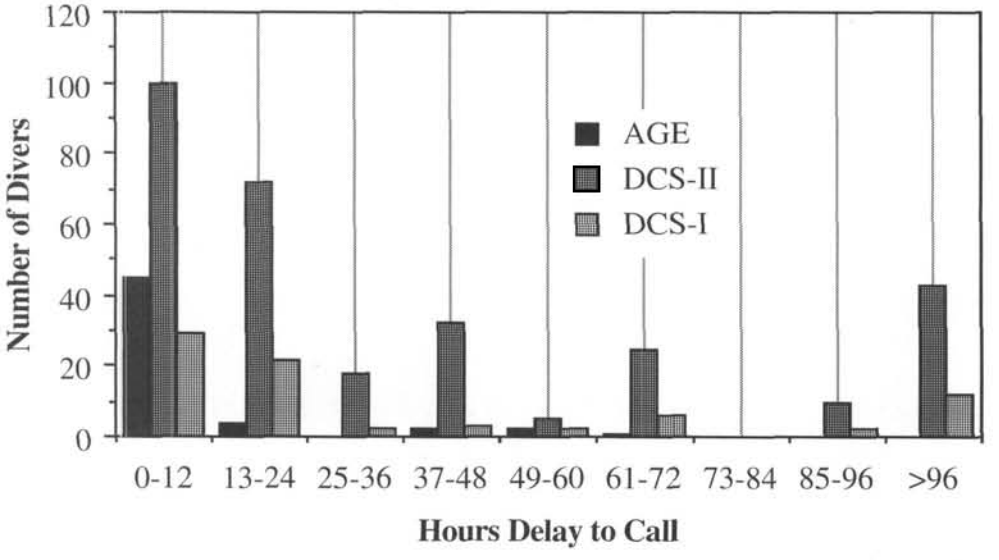
5.0 Treatment

Graph 5.1 Delay to Calling for Assistance

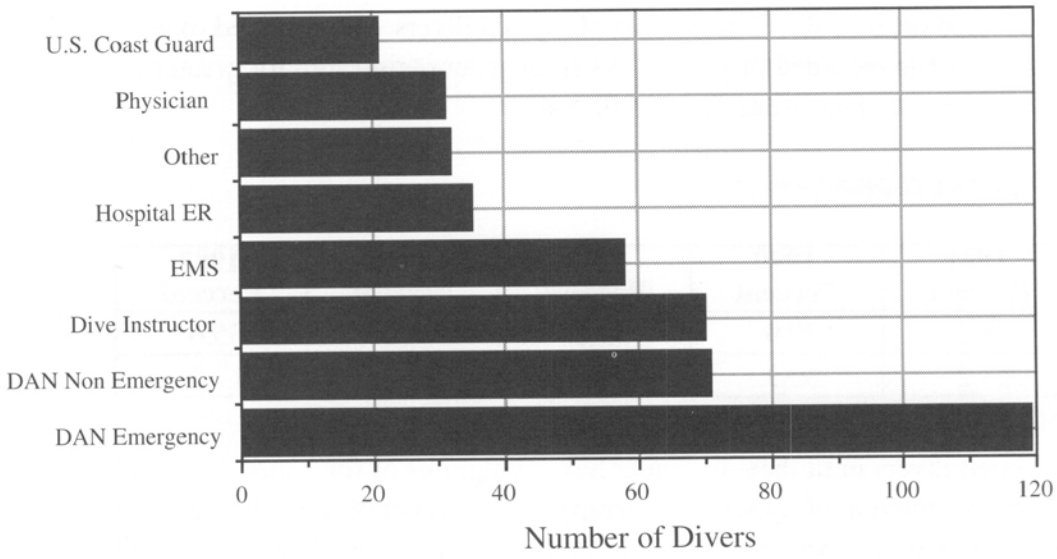


Approximately 50 percent of injured divers call for assistance within 12 hours of the onset of their first symptom. There are many reasons divers may delay seeking medical evaluation assistance. Some individuals may not feel their symptoms are serious enough to seek treatment, or may not recognize their symptoms as being related to decompression illness. Pain can easily be mistaken for the aches and pains associated with exertion. Additionally, a remote dive site may limit access to medical evaluation. Delays in seeking help naturally create delays in treatment. A delay in treatment may decrease the possibility of immediate and complete resolution of symptoms. It is necessary to understand the signs and symptoms of decompression illness in order to seek assistance and the earliest possible treatment.

Graph 5.2 Delay to Recompression

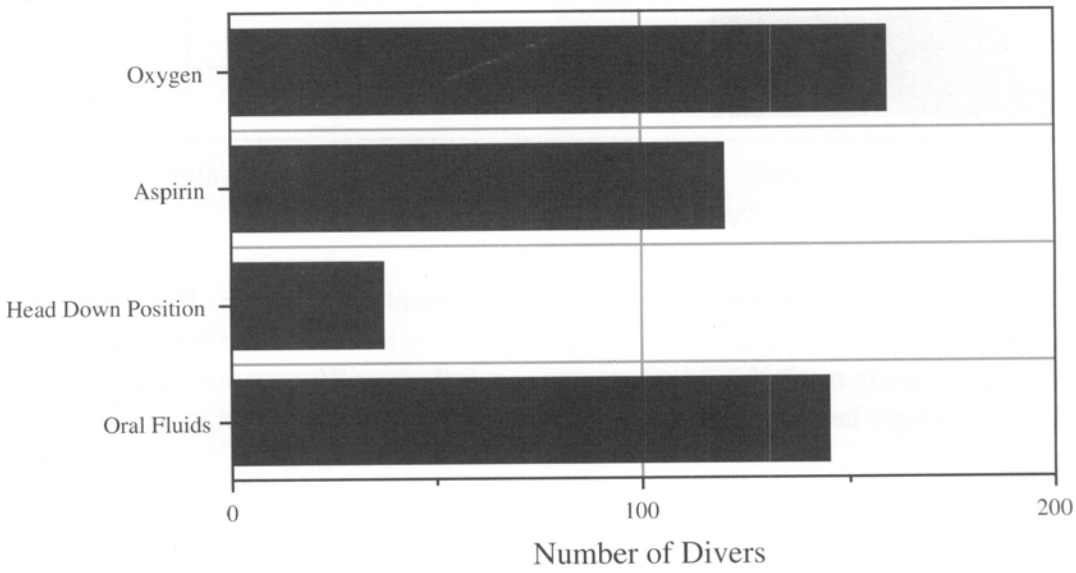


Graph 5.3 First Contact for Assistance



Evidence of the service DAN provides to injured divers is shown in Graph 5.3. Forty-one percent of injured divers used DAN as their first contact for help. DAN is often contacted by hospital emergency departments, local EMS, personal physicians, and the U.S. Coast Guard for emergency information and assistance. Advice is given on a range of topics including medical management for physicians untrained in diving medicine, as well as assistance in arranging air transport, as necessary. The "other" category includes contacts such as divemasters, hyperbaric chambers (or staff), dive club management, university dive technician, highway patrol, park service, certifying agency, boat leader or captain, and friends or dive buddies.

Graph 5.4 First Aid Used



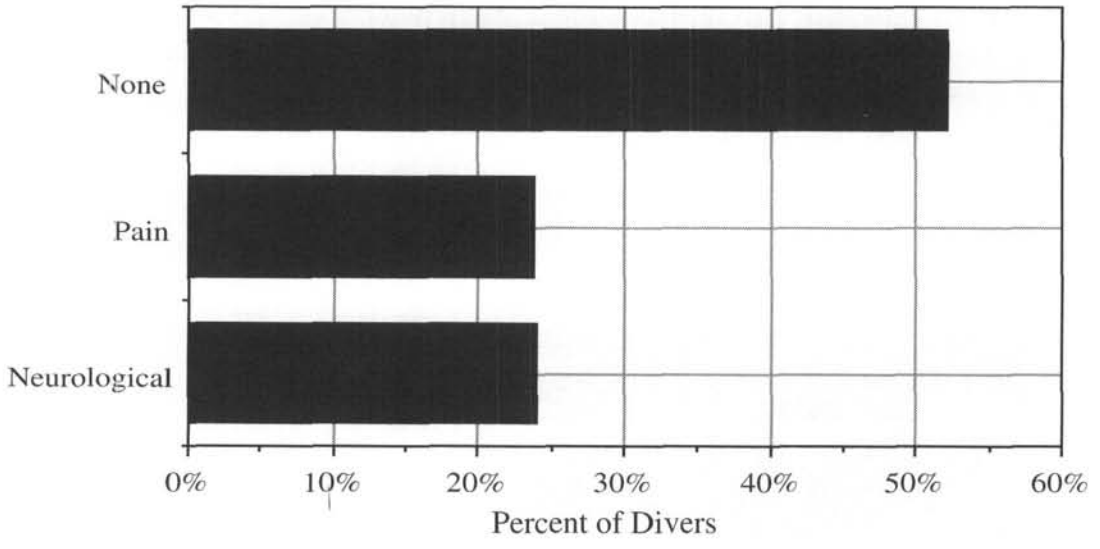
Graph 5.4 shows the type of help injured divers received before reaching a hospital. Table 5.5 shows that there was an increase in the use of both oxygen and oral fluids. However, 35.9 percent of all injured divers received no first aid. The percent of injured divers who received oxygen in 1991 is slightly above the percentage recorded in 1987. This is an encouraging sign for greater accident awareness and the delivery of appropriate first aid measures.

Table 5.5 Accident Management

	1991 Percent	1990 Percent	1989 Percent	1988 Percent	1987 Percent
Oxygen	36.4	30.9	33.2	34.0	35.6
Oral Fluids	33.2	30.3	23.8	18.7	17.0

DAN follows up injured divers until they no longer have symptoms or for 3 months, whichever comes first. After the completion of hyperbaric therapy, 47.8 percent of treated divers still had some residual symptoms. Twenty-four percent had a neurological residual and 23.8 percent had residual pain. At the three month follow-up interval, 16.5 percent of injured divers still had some symptom of injury. The post-treatment and three month residual percentages have been similar since 1987 when they were first recorded by DAN.

Graph 5.6 Post Hyperbaric Treatment Residuals



Decompression illness, like other injuries, often takes time to completely resolve. Permanent injury can occur in decompression illness. After five years of data collection, it is clear that hyperbaric therapy only provides complete resolution of symptoms in a little over fifty percent of all cases yearly. This percentage might be improved if more divers sought earlier treatment.

1991 Report on Diving Fatalities

6.0 Introduction to Diving Fatalities

The National Underwater Accident Data Center (NUADC) at the University of Rhode Island has been reporting diving fatalities for twenty years. Since 1989, Divers Alert Network (DAN) has been a collaborator in this effort. The 1991 report on scuba fatalities is the second joint effort published by DAN and NUADC. Only United States citizens who were recreational divers are reported, regardless of the location of death. Diving deaths while involved in professional or commercial diving are included in the occupation diving fatalities in Appendix G.

NUADC has attempted an estimate of the active diver population in order to determine the incidence of fatalities among active divers. In the past, NUADC has reviewed industry sponsored surveys and the "sport participation" survey of the National Sporting Goods Association to assist in a population estimate. The information from these studies and data collected from NUADC from the scuba training agencies has been used to establish an estimated active diver population of 2.5 to 3.2 million divers at the end of 1991. This estimate represents a small increase in active divers over 1990.

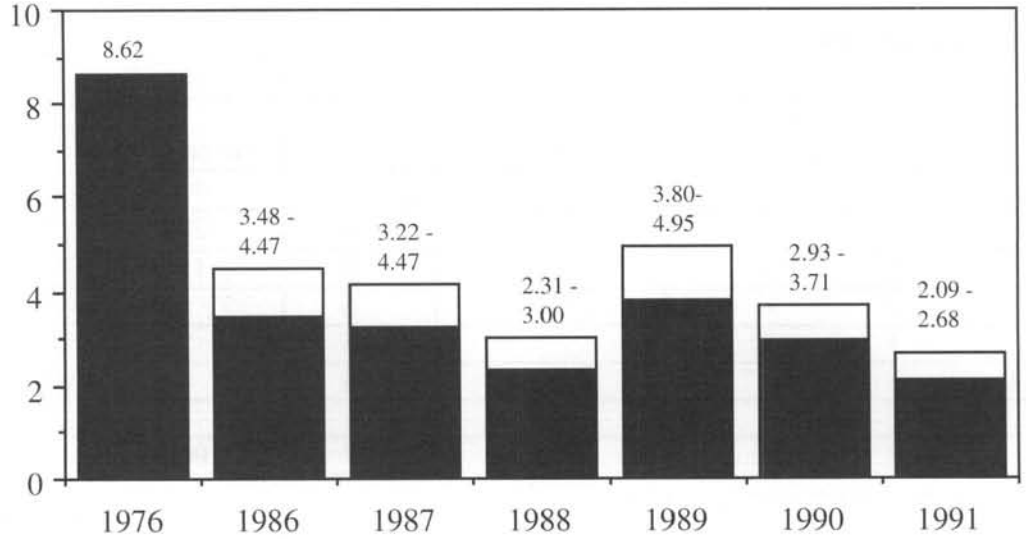
It is difficult to obtain the exact number of active divers. The number of newly certified divers is not available and there is no way to determine the number of divers who reenter scuba each year after a year or more of no participation. Additionally, not all divers remain active after the first year of diving, and there is no way to track the duration or exposure to scuba in these individuals. For these reasons an estimated range of "active divers" is best suited to describe the U.S. scuba diving population.

Graph 6.1 compares the estimated incidence of recreational scuba fatalities per 100,000 participants from 1991 to previous reporting years. These rates are based on data collected by NUADC. Using the 1991 estimate of 2.5 to 3.2 million divers, the estimated incidence for 1991 is 2.09 to 2.68 per 100,000 participants. For this estimate, active participants are assumed to be certified and uncertified recreational divers who have been active in scuba at least once in the year. Some fatalities have occurred in divers on their very first dive of the year.

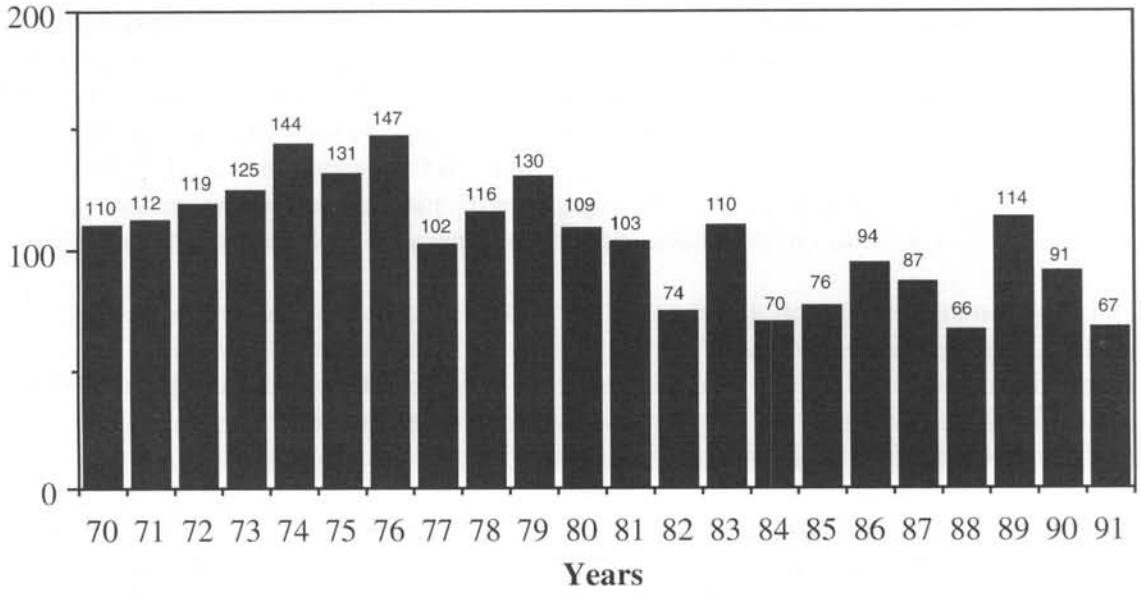
This estimated population and incidence rate has been given for many years, but there is no way to verify these numbers. The number of scuba-related deaths is showing a decreasing trend in recent years. Although these estimates cannot be verified, it is known that the total number of certified divers continues to grow annually.

A total of 67 recreational scuba fatalities were reported in 1991. Fifty-nine of these fatalities were certified divers and 8 were non-certified (with 4 under initial instruction). This is the second lowest number of scuba deaths recorded since 1970. The total number of U.S. scuba diving deaths decreased by 27 percent from the 1990 total. Unfortunately, at least 90 scuba related deaths have been reported for 1992.

Graph 6.1 Estimated Fatality Rate per 100,000 Active Divers per Year



Graph 6.2 Yearly U.S. Recreational Diving Fatalities



7.0 Methods of Fatality Data Collection

Table 7.1 Initial Contacts

	Inside United States	Outside United States	Total	Percentage
DAN Network*	19	10	29	43.3
Subscription Services**	13	1	14	20.9
Non-Members	6	2	8	11.9
Legal/Agency	6		6	8.9
USCG	5		5	7.5
Medical Examiners	4		4	6.0
Newspaper	1		1	1.5
TOTAL	**54**	**13**	**67**	**100.0**

* *General membership, network chambers and emergency line*

** *Luce, Compuserve, Burrell's*

Table 7.1 shows the people and agencies who served as the first contacts for reporting a scuba fatality in 1991. These reports were received by DAN in the mail, or by telephone. The percent of DAN network calls as a share of initial fatality contact increased from 35.2 percent in 1990 to 43.3 percent in 1991, and includes reports from the general DAN membership which increased from 18.7 percent to 29.9 for 1991. The network chambers accounted for 9.0 percent of initial contacts as opposed to 11.0 percent in 1990. Calls via the emergency line accounted for 4.5 percent of the 1991 fatalities versus 5.5 percent in 1990. Initial contacts from subscription services decreased from 31.9 percent in 1990 to 20.9 percent in 1991. Surprisingly, non-members accounted for 11.9 percent of first contacts in 1991. Investigative agencies, newspaper staff, medical examiners, private physicians and the United States Coast Guard accounted for the remainder of the initial contact sources.

The growth in DAN member contacts and the parallel decline in subscription service contacts may be due to an increasing awareness of DAN's effort to analyze diving related fatalities. This shift also reflects the speed and improved quality of the information received. Contacts from general DAN membership generally occur within one week of the incident, whereas contacts from the subscription services may occur one to three months after the incident.

When contacting sources shortly after a fatality, DAN is often able to obtain more data. Because diving fatalities are rare, investigating agencies may be unfamiliar with scuba fatality investigations or with DAN's efforts to collect data. Early communication with investigators and medical examiners usually produces the information needed for an accurate description of the fatality. DAN offers assistance and information concerning scuba fatalities when needed.

Table 7.2 shows the information sources for 1991. All United States citizens who were doing recreational diving and who were not involved in a commercial activity are included. DAN verifies each fatality through local authorities, medical services, or regional newspapers. Following the verification of each incident, DAN requests copies of autopsy reports, investigation reports, and where possible, witness statements. DAN analyzes the cumulative database to identify contributing conditions and common trends. The quality of this report depends on the detail and accuracy of the reporting agencies and individuals. The most accurate identifying factors are autopsy reports, a thorough investigative report, and witness/family statements. In the above table, we do not distin-

Table 7.2 Primary Sources of Information

Autopsy, investigative/coroner report and family/witness interview	8
Autopsy and investigative/coroner report	29
Autopsy and local contact/family or witness interview	12
Autopsy and news clippings	3
Investigative report	5
Local contact	5
Witness	2
Newspaper only	3
TOTAL	**67**

guish between the reports containing witness statements and those that do not. Where family or witness interviews have been noted, DAN has either spoken directly with an individual or has received a written statement not included in the investigation report. Such individuals can generally report details regarding the deceased's dive experience and medical history.

An autopsy report and information was available to DAN in all but 14 fatality cases. In nine instances an autopsy was not performed. The decision to perform an autopsy usually is the responsibility of a local medical examiner who follows guidelines established by the local jurisdiction. There were five cases in which no body was located. Detailed investigations are very important in these cases, since limited medical conclusions can be drawn without an autopsy. Main sources of information in these 14 cases include investigation reports, local contacts, witness/family interviews, and news clippings. DAN obtained more complete information in a higher number of cases then in the past two years, and has seen an increase in the amount of data from family, friends and witnesses.

Location of Diving Fatalities

The following tables show the site distribution of scuba diving fatalities in and outside the United States. The percentage relates the fatalities at a location to the total number of fatalities. One cannot conclude that a high number of fatalities in an area indicates that it is more dangerous than another.

In the United States, scuba diving activity is concentrated in Florida and California. Non-residents, as well as residents, frequent these areas. Thus, Florida and California may be expected to have the greatest number of fatalities. Scuba fatalities in the United States decreased by 21 percent in 1991. The state of Florida recorded 14 scuba fatalities in 1991, down from 22 deaths in 1990. Three of the 1991 Florida deaths occurred in caves as compared to eight cave fatalities in 1990 (plus one cavern diving fatality). There were 10 scuba fatalities in California in 1991 while 14 were noted in 1990.

Pennsylvania had a total of four deaths in 1991. Two deaths occurred at each of the popular quarry diving sites. Two occurring in the same quarry, several months apart, happened while the victims were undergoing scuba instruction. There were only two Pennsylvania scuba fatalities during 1990.

New Jersey doubled its number of scuba fatalities for 1991 with four wreck-diving deaths.

Hawaii accounted for three scuba fatalities in 1991, the same as the previous year.

Two fatalities were recorded in Texas (offshore in the Gulf of Mexico). One of these victims died of

Table 7.3 Location of Diving Fatalities by State

	Certified	Uncertified	Total	Percentage
Florida	12	2	14	25.9%
California	10		10	14.9%
New Jersey	4		4	6.0%
Pennsylvania	2	2	4	6.0%
Hawaii	1	2	3	4.5%
Missouri	2		2	3.0%
New York	2		2	3.0%
Tennessee	2		2	3.0%
Texas	2		2	3.0%
Delaware	1		1	1.5%
Georgia	1		1	1.5%
Indiana		1	1	1.5%
Maine	1		1	1.5%
Michigan	1		1	1.5%
Minnesota	1		1	1.5%
North Carolina	1		1	1.5%
New Mexico	1		1	1.5%
Nevada		1	1	1.5%
Oregon	1		1	1.5%
Washington	1		1	1.5%
TOTAL	**46**	**8***	**54**	**85.8%**

** Includes people under initial instruction.*

hypothermia after 20 hours in the water without a wet suit (while his wet suited partner survived). The other was a spearfisherman diving alone.

The total number of fatalities among U.S. citizens in foreign countries exceeds any individual state. As with U.S. sites, this most likely represents the popularity and frequency of diving at these locations. During 1991, fatalities outside the U. S. decreased by 4.5 percent.

Scuba deaths of U.S. citizens occurring in foreign areas totaled 13 in 1991. Mexico again headed the list with five that occurred in Cozumel. The Bahama Islands accounted for three fatalities and one death each were reported in Okinawa, Palau, Dominica, Bonaire, and St. Maarten.

Table 7.4 Location of Diving Fatalities Outside the United States

Mexico	5	7.5%
Bahamas	3	4.5%
Bonaire	1	1.5%
Dominica	1	1.5%
St. Martin	1	1.5%
Okinawa	1	1.5%
Palau	1	1.5%
TOTAL	**13***	**19.5%**

** All were certified divers.*

8.0 Dive Profile

Dive Activity and Certification Status

Scuba divers can participate in numerous activities with various skill and stress levels while diving. The activity can be a very easy dive on a warm, clear reef; or a physically and mentally challenging dive on a wreck in a strong current with limited visibility. Whatever the diver's choice, the conditions of the dive should be consistent with training, experience and comfort zone.

Table 8.1 Primary Dive Activity

Primary Dive Activity	Certified to Scuba Dive	Not Certified to Scuba Dive	Total	Percent
Pleasure	32	3	35	52.2%
Under Instruction	5	4*	9	13.4%
Spearfishing/Hunting	4	1	5	7.5%
Wreck - no penetration	4		4	6.0%
Photography	3		3	4.5%
Collecting/Work/Task	2		2	3.0%
Technical Level Dive:	-	-	-	-
Cave	7		7	10.4%
Deep (>150 fsw)	2		2	3.0%
TOTAL	**59**	**8**	**67**	**100.0%**

** Undertaking initial training.*

Table 8.1 shows the number of certified and non-certified divers by their primary activity. Here, "certified" means the person has received at least the minimum open water training. "Primary activity" is the main objective of the dive as determined from investigation reports or witness statements. Although the diver may have a second activity, only the predominant objective is considered in this analysis. For example, if divers are hunting in a wreck, then their primary activity is hunting.

The fatality section of this report deals primarily with certified divers. In some of the analysis, accidents are separated into two categories. The first includes people who were certified or were under the supervision of a qualified instructor. The second includes divers without diving credentials. In the first category, there are 63 divers (94 percent of all fatalities). Fifty-nine divers (88.1 percent) were certified to dive while four were undertaking their initial training. The second category of fatalities contains four divers (6 percent) without proper certification or supervision.

Fifty-two percent of the total 1991 fatalities occurred during pleasure dives. Since sightseeing is the most popular activity, it is expected that most deaths would happen to individuals engaged in this activity. Divers under instruction accounted for nine (13.4 percent) of the total fatalities. Four divers were taking their initial training, while the remaining five were taking advanced level classes.

Individuals doing technical level dives accounted for another nine (13.4 percent) of the total fatalities in 1991. As stated in ***Technical Diver***, "Technical diving is a discipline that utilizes special equipment and methods to improve underwater safety and performance, enabling divers to extend their range beyond the established recreational envelope." Technical level dives include cave dives, wreck penetration dives, ice dives, and deep, extensive, decompression dives. Three double fatalities in caves accounted for six of the seven cave deaths. None of these individuals were trained for cave diving. One of the two deep diving deaths was also untrained in technical level diving. Recreational divers may be trained to safely enter overhead environments; however, they must remain within the limits set by the respective agencies. Technical divers have invested significant amounts of time and money to safely accomplish dives. Seven of these nine fatalities did not have training or experience for technical level diving.

Table 8.2 Dive Platform

	1991		1990	1989
Entry	Frequency	Percent	Percent	Percent
Shore	29	46.0%	45.0%	24.6%
M/V* (charter)	19	30.2%	35.0%	39.5%
M/V* (private)	14	22.2%	20.0%	34.2%
Pool	1	1.6%		1.8%
TOTAL	**63**	**100.0%**	**100.0%**	**100.0%**
			n = 80	*n* = 114

** M/V = Motor Vehicle*

Dive Platform and Number of Divers in the Group

Table 8.2 illustrates the dive platform used for certified divers. All four fatalities of uncertified divers for 1991 were done from shore. Three of these cases were solo diving, but other members of the dive party were in the water at the time of the accident.

The number of charter boat fatalities decreased again from 35.0 percent of 1990 fatalities to 30.2 percent in 1991. After increasing from 1989 to 1990, the number of shore-based fatalities in 1991 remained about the same at 46.0 percent. All three double fatalities were shore-based. In 11 of the shore entry deaths, all members of the dive team were in the water, including 5 solo divers and 6 buddy teams of 2 divers each. None of the 11 cases were multiple fatalities. Only one fatality occurred in a pool in 1991.

In two of the private motor vessel entries, all members of the dive team were in the water. In fatalities that occurred while diving from charter boats, there were other divers and crew members on the boat able to lend assistance. The individual that died in the pool had no buddy or surface observer present.

Table 8.3 Number of Divers in a Group

Number in Dive Party	Frequency	Percent
1	6	9.5%
2	8	12.7%
3	10	15.9%
4	7	11.1%
5	1	1.6%
6	3	4.8%
7	6	9.5%
8	8	12.7%
9	1	1.6%
10 or more	8	12.7%
Unknown	5	7.9%
TOTAL	**63**	**100.0%**

Table 8.3 shows the number of individuals in the dive group at the time of the incident. This includes all divers and associated shore or boat personnel. Generally, this also represents the total number of people at the scene of the fatality; however, there may actually be more people present. For example, a group may be one of many groups at a quarry. Only the number of participants that are associated with the fatality are considered.

As seen from this table, 49.2 percent of the fatalities had been diving in small groups of four or fewer divers. None of these occurred on a charter boat. During 1990, 43.9 percent of fatalities were in similar small groups. In 1991, there were six solo diving fatalities who had no surface support; while in the remaining two, there were at least two surface observers.

Eight fatalities occurred in a dive group of two. In each case, both people were in the water. Buddy separation was a factor in 6 of the cases. In the seventh case, a diver had a cardiac problem at the surface; while in the eighth, a diver was hit by a wave and aspirated water.

There were 44 cases where multiple divers were in the water and surface personnel were also present. Of these, buddy separation was a factor in 23 cases. Contributing factors in the remaining cases were 9 with cardiac and other medical problems, 6 double fatalities (3 cases), 2 with environmental factors, 1 use of a new equipment set-up, 1 unexplained embolism, and 2 victims who were out of air.

9.0 Certified Diver Population

Table 9.1 shows the distribution of scuba fatalities by age. The data in this table and this section refer only to those divers who were formally trained or under the supervision of a qualified instructor at the time of death.

The youngest diver was 16 years of age and the oldest was 72. Only 20.7 percent of all fatalities were fifty years of age or older. This is down from 22.5 percent of 1990 certified divers and 27.8 percent of divers in 1989. The number of reported cases in the 19 years and younger age group also decreased from both 1989 and 1990.

Despite the fact there was one less female death in 1991 (16 deaths), the percent of female deaths was 25 percent in 1991 compared to 22.5 percent in 1990. There were only ten female deaths in 104 certified divers in 1989 which was a very low percentage (8.8). The record number of female deaths occurred in 1978 when 21 deaths occurred out of 144 total fatalities.

It is difficult to explain all of the variation in yearly fatality trends. However, some of the changes may be due to the size of the population that is analyzed each year. The differences in male and female divers may be due to different styles of diving, or health problems such as cardiovascular disease in the older population. A complete breakdown of causes of death and related health problems is described in section 10.0.

Table 9.2 shows the distribution of highest levels of certification for the 1991 fatalities. Fifty-nine percent of the fatality cases held basic certification or were taking their initial training. Seventy-three percent of this group were considered novice or inexperienced divers with only 1 - 20 dives. Divers with entry level training have the minimum basic skills, experience, and knowledge to engage in controlled diving activities in conditions similar to the training environment. Additional training is recommended to become familiar with different environments and conditions such as current and limited visibility. Progression should be slow enough to gain comfort and confidence with diving skills.

Only 9.5 percent of the certification levels for 1991 are not known, as compared to 21.3 percent in 1990. This is an illustration that the quantity and quality of information received on fatality cases is improving.

Table 9.3 shows the distribution of overall experience levels with the criteria used to establish them. The analysis is based on the total number of dives because it is difficult to obtain the exact number of dives made or length of time since the last dive.

Of the 19 experienced divers, at least 61+ dives, eight had cardiovascular events and two may have been cardiac related, two bodies were not located, one was trapped in a cave, and one uncertified cave diver became entangled in a guideline while traversing a cave. Two divers had air consumption problems.

Table 9.1 Age and Sex Comparison of 1991 Fatalities

Age	Male	Female	Total	Percent
10 - 19	2		2	3.2
20 - 29	6	4	10	15.9
30 - 39	14	6	20	31.7
40 - 49	15	3	18	28.6
50 - 59	7	2	9	14.3
60 - 69	2	1	3	4.8
70 - 79	1		1	1.6
TOTAL	**47**	**16**	**63**	**100.0**

Table 9.2 Certification Level of 1991 Fatalities

Student*	4	6.3%
Basic/Open Water	33	52.4%
Advanced	9	14.3%
Rescue	2	3.2%
Dive Master	1	1.6%
Instructor	5	7.9%
Commercial	1	1.6%
Military	2	3.2%
Unknown level	6	9.5%
TOTAL	**63**	**100.0%**

** Under initial training.*

Table 9.3 Diving Experience in Fatalities

	Within Activity or Environment		Overall Experience	
Uncertified	7	11.1%	-	-
Novice (≤ 5 dives)	17	27.0%	10	15.9%
Inexperienced (6 - 20 dives)	9	14.3%	18	28.6%
Intermediate (21 - 40 dives)	4	6.3%	4	6.3%
Advanced (41 - 60 dives)	2	3.2%	3	4.8%
Experienced (≥ 61 dives)	15	23.8%	19	30.2%
Unknown	9	14.3%	9	14.3%
TOTAL	**63**	**100.0%***	**63**	**100.0%***

** Percent of certified divers.*

10.0 Medical Issues in Scuba Fatalities

Table 10.1 Known Medical Conditions

Age	CVD*	Diabetes	Pulmonary Problem	Asthma	Emotional Considerations	Chemical Dependency	Total
20-49			1	2	1	1	5
50-79	4	2					6
TOTALS	**4**	**2**	**1**	**2**	**1**	**1**	**11**

* *Cardiovascular Disease*

Causes of Death

The fatalities in this report were assigned cause of death and contributing factors using the *International Classification of Disease-9th revision-Clinical Modification* (ICD-9-CM) based on the World Health Organization's *International Classification of Diseases.*[1] The ICD-9-CM codes which were used are listed in Appendix H. The cause of death as listed on the death certificate was accepted in the majority of cases when the death certificate or autopsy report was available. In other cases the cause of death was determined based on the information available. In a few cases, there was insufficient information available.

Autopsied Cases

Autopsies were performed on 53 of the 67 fatality cases during 1991 by various medical examiner jurisdictions. For 1991, DAN received autopsy results in all incidents representing 79.1 percent of the total cases and 100 percent of the autopsied cases. In 1990, the autopsy rate was 68.1 percent of total fatalities, and we received 81.6 percent of the reports. (There is a slight change in published data for 1990 because we received information after publication of the report.) We also obtained an investigation report in 37 of 53 autopsied cases for 1991.

As seen by the increase in the percent of autopsy reports and investigation reports received, DAN obtained more complete information in a higher number of cases then the past two years. DAN has also seen an increase in the information from family, friends, and witnesses. These individuals can generally reveal important details regarding the deceased's dive experience and medical history.

Cerebral Arterial Gas Embolism

There were 9 deaths due to cerebral arterial gas embolism. Six of the nine were immediate deaths due to cerebral arterial gas embolism (DAN # 1, 17, 20, 34, 46, 51). The remaining three were drowning deaths as a result of cerebral arterial gas embolism (DAN # 16, 19, 65). There were a variety of causes of the cerebral air embolisms including air supply problems, panic, an emphysematous bleb and possibly breathholding. The following cases are described in detail.

Case Reports — Cerebral Arterial Gas Embolism

DAN Record Number: 1

Cause of Death

Immediate: Air embolism	ICD-9-CM: 958.0
Due to: Rapid ascent	ICD-9-CM: E902.2
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Pneumothorax, tension	ICD-9-CM: 860.0

The decedent was a 45-year-old male taking photographs while his buddy was spearfishing. They became separated and a witness reported seeing the victim surface, wave his arms and sink. He was found just below the surface in kelp. His tank was empty, and he was wearing his weight belt. He apparently made a rapid ascent after running out of air. The autopsy findings were consistent with air embolism.

DAN Record Number: 17

Cause of Death

Immediate: Cerebral edema	ICD-9-CM: 348.5
Due to: Cerebrocortical necrosis	ICD-9-CM: 437.9
Due to: Air embolism	ICD-9-CM: 958.0
Due to: Barotrauma	ICD-9-CM: 993
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Emphysematous bleb	ICD-9-CM: 492.0
2. Decompression sickness	ICD-9-CM: 993.3

This was a 31-year-old male with a history of decompression sickness with hemiparesis treated in 1986 with apparent full recovery. He subsequently at some time was involved in a motor vehicle accident with lung damage. Prior to his final dive he had experienced back pain sufficient to cause him to consult a chiropractor during the final two months.

The statements by the dive buddy indicate a fairly uneventful dive until decedent reached the 15 foot safety stop. A friend on the shore saw the decedent surface without signs of distress. He was next found unconscious in about 10 feet of water. He was rescued, resuscitated and eventually transported to a hospital where he received U.S. Navy Treatment Table 6A plus resuscitative measures. The hospital summary is not available, but death occurred about 100 hours after the accident. This may represent an "undeserved" air embolism with air trapping in the bleb in the right upper lobe of right lung. There is no way of knowing whether or not he held his breath during the last part of ascent. The tank contained 1,300 psi according to the investigative report.

DAN Record Number: 20

Cause of Death

Immediate: Air embolism	ICD-9-CM: 958.0
Due to: Rapid ascent	ICD-9-CM: E902.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Coronary arteriosclerosis, slight	ICD-9-CM: 414.0
2. Obesity, moderate	ICD-9-CM: 278.0

This was a new diver, a 31-year-old male, making his first open water scuba dive since his certification. He was in a quarry with poor visibility. He apparently made an uncontrolled rapid ascent and was unconscious at the surface. He died during resuscitation attempts. The autopsy results are consistent with the recorded diagnoses.

DAN Record Number: 34

Cause of Death

Immediate: Air embolism	ICD-9-CM: 958.0
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 49-year-old male experienced diver making a 130 fsw dive for 11 minutes followed by a decompression stop at ten feet. The sea state was rough with "five to seven" foot seas. After the decompression stop, the decedent collapsed on the boat ladder while trying to board. He was rescued with difficulty because of the sea state and his equipment (which was discarded into ocean). He was transported to a local hospital in cardiac arrest and could not be resuscitated. Autopsy disclosed bubbles in the right atrium and coronary veins as well as cerebral veins.

DAN Record Number: 46

Cause of Death

Immediate: Air embolism	ICD-9-CM: 958.0
Due to: Barotrauma	ICD-9-CM: 993
Due to: Asthma	ICD-9-CM: 493.9
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Left ventricular hypertrophy	ICD-9-CM: 429.3
2. Coronary artery disease (mild)	ICD-9-CM: 414.0

The decedent was a 38-year-old male with a history of asthma. He was on his third open water training dive and was practicing buddy breathing with the instructor while ascending. At the surface the decedent was found to be unconscious by the instructor who performed CPR, which was continued to the hospital where the decedent was pronounced dead. At autopsy numerous air bubbles were found within the coronary circulation and in the cerebral veins, but not arteries. The near instant death and embolization of coronary arteries suggest a cardiac death. The combination of asthma and ascending while buddy breathing was fatal.

DAN Record Number: 51

Cause of Death

Immediate: Air embolism	ICD-9-CM: 958.0
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Exogenous obesity	ICD-9-CM: 278.0
2. Chronic lymphocytic thyroiditis	ICD-9-CM: 245.2

A 57-year-old female with two years diving experience and approximately 26 dives was diving in the tropics. On day six of her diving vacation she developed difficulty at the end of an uneventful dive. She required assistance to regain the boat and then developed cardiopulmonary collapse. She was resuscitated and transported to local hyperbaric clinic followed by air evacuation to the U.S. She remained deeply comatose and experienced cardiac arrest in the emergency department at the U.S. hospital. After resuscitation she received U.S. Navy Treatment Table 6 without benefit and died approximately 24 hours after injury. Air embolism was the suspected cause of death as autopsy revealed multiple infarcts in brain. The thyroid disease may have contributed to the death.

Case Reports — Drowning / Cerebral Arterial Gas Embolism

DAN Record Number: 16

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Air embolism	ICD-9-CM: 958.0
Due to: Rapid ascent	ICD-9-CM: E902.2
Due to: Insufficient air	ICD-9-CM: E913.2

Other significant conditions contributing to death but not resulting in underlying cause

1. Panic state	ICD-9-CM: 308.0

The decedent was a 26-year-old male who made a 130 fsw dive for 25 minutes using "independents" (twin tanks without manifold). He was reported to have done only a few dives with this equipment. Approximately 20 minutes after the dive began he attempted to use his buddy's regulator, but could not. He became unconscious at depth and was brought to the surface by fellow divers. He was apparently in cardiac arrest at that time.

On investigation the equipment was in working order; however, one tank was empty and the other contained 3,400 psi. The autopsy revealed air in cerebral vessels as well as pericardial and epicardial vessels.

This is coded as rapid ascent because there is no code for breathhold ascent. The decedent was probably not breathing during rescue to the surface and in effect was ascending while breathholding.

DAN Record Number: 19

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Air embolism	ICD-9-CM: 958.0
Due to: Rapid ascent	ICD-9-CM: E902.2
Due to: Insufficient air	ICD-9-CM: E913.2

Equipment unfamiliarity may have precipitated the drowning death secondary to embolism of a 30-year-old female who had been certified about five years. She was diving from a private vessel in about 45 fsw. She and her buddy began their ascent together. She had 600 psi in her tank when beginning ascent. During the ascent she signalled to her buddy that she needed to share air, which they did for a brief time. Her cylinder was equipped with a J-valve which the diver must operate in order to obtain the last 300 psi of air. The buddy noted that the J-valve was up and attempted to pull it down. However, she started struggling and pushed him away, then made a breath hold ascent. She was seen to reach the surface and then sink.

When the equipment was examined, the J-valve was in the up position and there was 375 psi air remaining in the cylinder. The decedent was wearing a 12-pound weight belt, excessive for her as she was wearing only a bathing suit.

DAN Record Number: 56

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Air embolism	ICD-9-CM: 958.0
Due to: Rapid ascent	ICD-9-CM: E902.2
Due to: Panic state	ICD-9-CM: 308.0
Due to: Scuba diving	ICD-9-CM: E910.1

While doing a navigation exercise during the fourth open water check out dive, a 28-year-old female unintentionally descended below the thermocline. Her buddy helped her ascend, but she started thrashing and struggling. Reportedly, she then used the deflator instead of the inflator to establish buoyancy. The buddy was unable to lend further assistance, so he surfaced and called for help. The body was located after a one hour search. The autopsy indicated the cause of death was drowning secondary to air embolism.

Cardiovascular Disease and Diving

Sudden Death in Diving

The fatality which occurs during scuba diving is a sudden, unexpected event involving a presumably healthy individual. The victim is usually not rescued in time to allow resuscitation and consequently there are very few deaths which occur after the victim is admitted to a medical facility. Although these fatalities are sudden and unexpected the sequence of events leading to the fatality is quite clear in nearly all cases.

Sudden death due to cardiovascular disease is common in the U.S. striking 200-400,000 Americans

per year and is responsible for 15-20 percent of deaths in adults. It is not surprising that a few such events occur to individuals while scuba diving. A definition of sudden death is as follows:[2]

1. Sudden event rendering the patient unconscious until death
2. Death occurring within 24 hours of the sudden event
3. Decedent participating in regular activities until the event
4. Not hospitalized when event occurred.

Most scuba fatalities fall within this definition; however, the cause of the fatality can generally be understood.

Sudden Death During Exercise

It is useful to consider the causes of sudden death occurring while an individual is engaged in exercise such as jogging, tennis, etc. Aside from accidental death the causes of sudden death during exercise in the young (below age 30) are mostly cardiovascular disorders of many types with the occasional exception of an infectious cause. The most common of these events is due to hypertrophic cardiomyopathy. When recognized, hypertrophic cardiomyopathy is a contraindication to scuba diving. However the diagnosis is difficult to make in the individual without symptoms. There was no scuba death in 1991 due to hypertrophic cardiomyopathy although there have been in prior years.

A brief discussion of the demand placed on the cardiovascular system by diving may assist in understanding sudden cardiac death which occurs during diving. The *cardiovascular response* to diving derives from several effects: Exercise stress, cold stress, and emotional stress.

Physical stress from exercise and cold results in increased oxygen consumption and increased work load for the cardiovascular system. Emotional stress may result in an acute anxiety reaction causing tachycardia (very rapid heart rate), elevated blood pressure and hyperventilation. These stresses may result in dysrhythmia, angina and sudden death in the presence of cardiovascular disease.

Anxiety can produce a sinus tachycardia (a rapid and forceful heart rate) of which the individual becomes acutely aware. This awareness of a markedly increased heart rate can result in rapid breathing which, in turn, creates a reverberating circuit of increased, anxiety-associated heart rate and respiration rate. The panic or acute anxiety may cause a massive sympathetic discharge of catecholamines which cause very high blood pressure levels and pulse rate of 170-180 per minute. A vagal response causing increased parasympathetic activity may result in bradycardia (slow pulse rate), hypotension, and fainting.

The normal breathing rate is around 15 breaths per minute. A person in panic, breathing rapidly, can achieve a rate of about 35 breaths per minute. Egstrom found that a diver at 60 feet, with approximately 300psi of air remaining in the tank, breathing at high rates, such as 35 breaths per minute, will overbreathe the average regulator. The regulator simply cannot handle this exaggerated level of breathing requirement and will not provide needed air. This condition contributes further to the lack of adequate ventilation.[3]

These stresses demand increased output from the heart and an increased blood flow through the coronary arteries. If there is coronary artery disease producing obstruction, blood flow becomes

inadequate for the working heart muscle. The result may be angina pectoris (chest pain), lethal rhythm disturbances or heart failure.[4]

Cardiovascular disease was a common cause of death during 1991 in the group of fatalities over age 40. There were nine deaths immediately caused by myocardial infarction and an additional five deaths from drowning after myocardial infarction. These 14 deaths represent 50 percent of the total in this age group. There were an additional four victims who had a cardiovascular disorder as a contributing cause. These included both hypertension and coronary artery disease. In the age 40 and under group, there were two deaths from drowning with cardiovascular disease as a contributing factor. Thus at least 20 victims had cardiovascular disease severe enough to have disqualified them as divers. See Graphs 10.3 and 10.4.

These deaths represent a challenge in prevention. A myocardial infarction which happens to a tennis player or jogger does not place the individual in further jeopardy from the environment. However a diver who develops a heart attack during a dive may drown because of inability to maintain control in the water. The diver with risk factors for coronary artery disease including sex, age, smoking, hypertension and other life style characteristics should have a careful examination to search for the disease.

Syncope

The individual who has a sudden loss of consciousness has had a syncopal episode or syncope. The most common cause has a cardiovascular basis with decreased cardiac output causing decreased cerebral blood flow and the resultant hypoxemia (low blood oxygen) results in cerebral ischemia and loss of consciousness. There may be many reasons for the reduced cardiac output which results in syncope. Common causes are arrythmias and conduction disturbances in the heart which produce a very slow rate (35 or below) or a very rapid rate (150-180 or more). These disturbances are frequently the result of coronary artery disease.

Other causes of reduced cardiac output leading to syncope may be peripheral vasodilation, decreased return of blood to the heart through the veins, low blood volume, and obstruction to cardiac output. Syncope in apparently healthy people is common and occurs for a variety of reasons. A forceful Valsalva maneuver can produce unconsciousness because the increased pressure within the chest limits the return of blood to the heart. This form of syncope occurs occasionally in weightlifters.

The simple faint is a form of syncope due to peripheral dilation of blood vessels as a result of many different stimuli. The person who faints due to apprehension about a needle stick or minor injury is familiar to all. Anxiety which may range from mild to the panic attack may produce syncope by the mechanism of hyperventilation. The anxiety leads to hyperventilation which causes hypocapnia (low CO_2 content in blood) producing cerebral vasoconstriction, decreased brain perfusion and unconsciousness.

Effort or exercise syncope may occur in the person with obstruction to cardiac output so that normal activity is tolerated, but there is insufficient response to the demand for cardiac output resulting from the exercise.

Postural hypotension (sudden drop in blood pressure on assuming upright position) occurs in individuals taking certain blood pressure medications as well as in a few apparently normal individuals taking no medication whatever.

Other causes of syncope not related to the cardiovascular system are less common and include such disorders as seizures, hypoglycemia (low blood sugar), and anaphylactic reaction. Causes of syncope specific to scuba diving include problems with nitrogen narcosis, oxygen toxicity, excessive carbon dioxide, contaminated breathing gas, and insufficient oxygen in the breathing gas.

There were several drownings which occurred after the diver appeared to lose consciousness. The drowning process itself was the probable cause in most of these cases. The diver with an interrupted air supply for any reason rapidly becomes hypoxic and may lose consciousness during reflex breath-holding prior to inhaling water.

There were several fatalities in which nitrogen narcosis appeared to play a major role and may have caused severely altered mental status if not unconsciousness prior to the drowning. The fatalities which occurred past 250 fsw were at risk for both oxygen toxicity and severe nitrogen narcosis.

Case Reports — Cardiovascular Disease

DAN Record Number: 3

Cause of Death

Immediate: Acute myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary atherosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Drowning	ICD-9-CM: 994.1
2. Scuba diving	ICD-9-CM: E910.1

The decedent was a 41-year-old male member of an elite military dive team and a very experienced diver. He was making a solo recreational dive and failed to return home. His wife notified authorities, and the body was found the next day. The autopsy disclosed acute myocardial infarction.

DAN Record Number: 9

Cause of Death

Immediate: Ventricular fibrillation	ICD-9-CM: 427.41
Due to: Coronary atherosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Cardiomegaly	ICD-9-CM: 429.3
2. Hypertensive vascular disease	ICD-9-CM: 402.0
3. Scuba diving	ICD-9-CM: E910.1
4. Tobacco abuse	ICD-9-CM: 305.1

The decedent was a 51-year-old experienced scuba diver and a member of an elite US military organization. He was hypertensive and a smoker. He had experienced difficulty on previous dives because of shortness of breath. He and a companion were diving in very shallow water (5-10ft), to gather stone crabs. The decedent was discovered unresponsive in cardiac arrest. The autopsy disclosed coronary atherosclerosis and cardiomegaly.

DAN Record Number: 11

Cause of Death

Immediate: Acute myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary atherosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Emphysema	ICD-9-CM: 490
2. Tobacco Abuse	ICD-9-CM: 305.1
3. Scuba diving	ICD-9-CM: E910.1

This was a 72-year-old male diving from a private boat. He had a history of emphysema and tobacco abuse. On entering the water he immediately developed distress and "shot to the surface." He was rescued and placed in the boat followed by CPR, but was dead on arrival at a medical facility. The autopsy was reported to be consistent with acute myocardial infarction.

DAN Record Number: 22

Cause of Death

Immediate: Acute pulmonary edema	ICD-9-CM: 428.1
Due to: Left ventricular failure	ICD-9-CM: 428.1
Due to: Anteroseptal myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary arteriosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Scuba diving	ICD-9-CM: E910.1
2. Diabetes mellitus	ICD-9-CM: 250.0
3. History of Prozac use (fluoxetine)	ICD-9-CM: E939.0

This was a 50-year-old male who had an undetected myocardial infarction several days or weeks prior to his fourth check-out dive. He was also diabetic and taking Prozac. He developed acute pulmonary edema during the dive. Resuscitation by his instructor was not successful.

DAN Record Number: 25

Cause of Death

Immediate: Acute pulmonary edema	ICD-9-CM: 428.1
Due to: Acute myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary arteriosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Cardiomegaly	ICD-9-CM: 429.3
2. Exogenous obesity	ICD-9-CM: 278.0

The decedent was an obese 58-year-old female clearly not physically qualified for scuba diving who got into difficulties while diving in the tropics. Autopsy results were consistent with coronary artery disease and acute myocardial infarction.

DAN Record Number: 32

Cause of Death

Immediate: Cardiac dysrhythmia	ICD-9-CM: 427.9
Due to: Hypertensive heart & renal dysfunction	ICD-9-CM: 404

Other significant conditions contributing to death but not resulting in underlying cause

1. Cardiomegaly	ICD-9-CM: 429.3
2. Diabetes mellitus	ICD-9-CM: 250.0
3. Obesity, exogenous	ICD-9-CM: 278.0
4. Scuba diving	ICD-9-CM: E910.1

The decedent was a male with morbid obesity, hypertensive cardiovascular disease, and diabetes experienced cardiac arrest at the end of a dive. He is reported to have been a diver for many years despite his physical problems.

DAN Record Number: 37

Cause of Death

Immediate: Left heart failure	ICD-9-CM: 428.1
Due to: Coronary artery disease	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Cardiomegaly	ICD-9-CM: 429.3
2. Scuba diving	ICD-9-CM: E910.1
3. Ethanol 0.17 percent	ICD-9-CM: 305.0
4. Codeine	ICD-9-CM: E935.2

The decedent was a male who had completed a diving course seven months earlier. He was diving in a swimming pool alone. His wife discovered the body on the bottom of the pool. Autopsy disclosed severe coronary artery disease and substance abuse (ethanol and codeine).

DAN Record Number: 50

Cause of Death

Immediate: Pulmonary edema	ICD-9-CM: 428.1
Due to: Coronary arteriosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Scuba diving	ICD-9-CM: E910.1

The decedent was female who had been certified as a diver in 1967 and who had made about 150 dives. She had no known medical problems and had undergone a physical shortly before the dive trip. She developed difficulty on the first dive while at about 40 fsw. She surfaced conscious and speaking, but developed cardiac arrest during rescue. Autopsy disclosed coronary artery disease and stenosis of left circumflex coronary artery.

DAN Record Number: 64

Cause of Death

Immediate: Acute myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary arteriosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Scuba diving	ICD-9-CM: E910.1
2. S/P CABG 3 vessel	ICD-9-CM: 36.13
3. S/P Myocardial infarction	ICD-9-CM: 412
4. Cardiomegaly	ICD-9-CM: 429.3

The decedent was a male who had known coronary artery disease with two previous myocardial infarctions and a three vessel coronary artery bypass graft procedure. This was the first dive since the surgery about one year prior. He surfaced, called for help and then developed cardiac arrest at the end of a relatively uneventful dive. The cause of death was determined to be acute myocardial infarction.

Case Reports — Cardiovascular Disease Contributing Cause of Death

DAN Record Number: 2

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Coronary artery disease (mild)	ICD-9-CM: 414.0

The decedent was a 52-year-old male diving on an offshore wreck at 80 fsw with one buddy. The buddy pair surfaced down current from the boat and were unable to reach it. The surviving buddy was picked up by another boat which then came across the body of the decedent who had dropped his tanks and weight belt and was floating on his back with buoyancy compensator inflated. He was in cardiac arrest when found. The medical examiner does not give a cause of death, but states pending further study. Intravascular gas bubbles are described, but after 80 feet, 40 minute plus dive, they are probably post mortem. The combination of cold water, hypothermia and mild coronary artery disease with maximum physical effort in swimming against current might have produced a dysrhythmia.

DAN Record Number: 8

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Coronary atherosclerosis (minimal)	ICD-9-CM: 414.0
2. Left ventricular hypertrophy	ICD-9-CM: 429.3
3. Cannabinoids present	ICD-9-CM: E980.3

The decedent was a 32-year-old male. He and his companions were attempting to dive in rough surf with poor visibility. The companions swam to a nearby jetty while the decedent attempted to swim ashore. He was discovered missing and found after a short search floating in the ocean unresponsive. Drowning was the cause of death with the minimal coronary artery disease a possible factor. Cannabinoids were also present. Left ventricular hypertrophy was present and is a marker for sudden death.

DAN Record Number: 18

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Coronary atherosclerosis, moderate	ICD-9-CM: 414.0

The decedent was a 46-year-old male with about 22 dives since certification. He was diving with companions on a wreck when he was discovered on the bottom with the free-flowing regulator out of his mouth. Companions attempted to inflate buoyancy compensator, but the tank was apparently empty due to the free-flowing regulator. His alternative air source (pony bottle) was full. The decedent was brought to the surface, but resuscitation was not possible. The decedent had complained about "upset stomach" and "tight weight belt" prior to dives. The death was due to drowning with coronary artery disease a contributing factor.

DAN Record Number: 23

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Acute myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary arteriosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Scuba diving	ICD-9-CM: E910.1

The decedent was a 40-year-old male who developed difficulties at the start of the dive and became separated from his buddy. His body was discovered about three hours later with the mask and one fin missing. The autopsy disclosed coronary atherosclerosis and myocardial infarction. The drowning followed the myocardial infarction.

DAN Record Number: 33

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Acute myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary arteriosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Cardiomegaly	ICD-9-CM: 429.3
2. Scuba diving	ICD-9-CM: E910.1

The decedent was a 43-year-old male who was making his third dive of the day and had just started the descent with his buddy after indicating, "OK." The buddy noticed the decedent not descending and returned to the surface. The decedent stated he had an "emergency" and then became unconscious. The buddy was unable to support the decedent at the surface and the body sank. Rescuers found the body after a one and a half hour search. The decedent wore all of his weight (26pounds) strapped to the tank.

DAN Record Number: 54

Cause of Death

Immediate: Instantaneous, undetermined cause	ICD-9-CM: 798.1
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Coronary artery disease (LAD & RCA)	ICD-9-CM: 414.0
2. Cardiomegaly	ICD-9-CM: 429.3

The decedent was a 40-year-old male and an experienced diver who was trying out new scuba gear in a shallow restaurant pond, when he encountered unknown problems and died. An employee of the restaurant observed the victim swimming underwater, stand up, remove and replace his mask, and then resubmerge. A short while later the victim was found floating face up with his head just underwater. The medical examiner reports the cause of death as unknown. However, the presence of coronary artery disease with cardiomegaly and the exertion of using scuba suggest a cardiac event as cause of death.

DAN Record Number: 59

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1
Due to: Entanglement (kelp)	ICD-9-CM: E918.4

Other significant conditions contributing to death but not resulting in underlying cause

1. Bicuspid aortic valve	ICD-9-CM: 746.4
2. Stenosing valvulitis	ICD-9-CM: 424.9
3. Left ventricular hypertrophy	ICD-9-CM: 429.3

The pathology report describes bicuspid aortic valve with stenosis and left ventricular hypertrophy (LVH). The stenotic lesion would produce a concentric LVH which demands increased blood flow due to the increased muscle mass, and is above normal resting values. Maximum blood flow is limited by the capillary bed and, under high load states, there are probably areas of myocardium underperfused. Ischemia could result in the absence of significant coronary atherosclerosis. The subendocardial zones will be affected first and rendered ischemic. This diver may have developed ischemia followed by a malignant dysrhythmia resulting in loss of consciousness and death by drowning.

DAN Record Number: 63

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Acute myocardial infarction	ICD-9-CM: 410.9
Due to: Coronary arteriosclerosis	ICD-9-CM: 414.0

Other significant conditions contributing to death but not resulting in underlying cause

1. Scuba diving	ICD-9-CM: E910.1
2. Biventricular hypertrophy	ICD-9-CM: 429.3

The decedent was a male who had discontinued a dive and returned to surface where he denied difficulty, but was observed to be coughing. He stated that he would rest on the surface. A short time later he was observed floating face down in the water and, on rescue, was in cardiac arrest. Autopsy revealed acute myocardial infarction and coronary artery disease.

Diabetes Mellitus

There were two deaths in individuals over age 40 who were diabetic. Both of these died of cardiovascular disease with diabetes a contributing cause.

Drowning

Drowning remains the most frequent cause of death in divers accounting for 61.2 percent of total 1991 deaths. Among the autopsied group, drowning was the immediate cause in 33 cases.

The drowning death follows the occurrence of factors which prevent the diver reaching or remaining at the surface. Buoyancy control is a fundamental part of the diving skill and not only makes diving pleasurable, it also is a self-rescue skill which should prevent drowning.

The inexperienced diver has probably not learned the technique well enough so that the responses are automatic. In a stressful situation, such as out of air and negative buoyancy, the diver responds inappropriately. As the buoyancy compensator inflation and deflation controls are operated by the same non-dominant hand in most designs, the stressed diver has only a 50-50 chance that the proper control will be activated when attempting to control buoyancy in an emergency. Even very experienced divers frequently make errors in pressing the proper button during routine dives. An inexperienced diver in panic attempting unsuccessfully to inflate a buoyancy compensator by depressing the deflate button will not make a decision to use the other button. Instead, in all likelihood, the diver will merely press the deflate button even harder. Several of the drowning deaths appear to fit the pattern of inability to control buoyancy even though the equipment is found to work properly and there is sufficient air in the tank. DAN case number 65 is probably an example of this problem.

The case discussions which follow are drownings arranged in subgroups according to our interpretation of the precipitating cause of the accident. The first group are those who were unable to reach the surface because of a physical barrier such as entanglement in lines or entrapment in an overhead dive site (wreck, ice, cave). The other groups are cases in which there were problems with air supply. The final group are cases with a variety of causes.

Case Reports — Drowning Deaths / Physical Barrier Preventing Access to surface

DAN Record Number: 4

Cause of Death

Immediate: Anoxic brain damage	ICD-9-CM: 948.1
Due to: Drowning	ICD-9-CM: 994.1
Due to: Scuba Diving	ICD-9-CM: E910.1
Due to: Entanglement (kelp)	ICD-9-CM: E918.4

Other significant conditions contributing to death but not resulting in underlying cause

1. Panic	ICD-9-CM: 308.0

The decedent was a 40-year-old female who was diving with her husband in kelp. She was known to have panic attacks while diving and had experienced one earlier that week. The buddy pair attempted a second dive and became separated shortly after entry. Searchers found the decedent with her octopus regulator entangled in kelp and buoyancy compensator inflator hose disconnected. She was rescued and resuscitated, but died about 48 hours later of anoxic brain damage.

DAN Record Number: 5

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba Diving	ICD-9-CM: E910.1
Due to: Entanglement (kelp)	ICD-9-CM: E918.4

Other significant conditions contributing to death but not resulting in underlying cause

1. Panic	ICD-9-CM: 308.0

The decedent was a 49-year-old male who was an inexperienced diver. The incident dive was his second open water dive since certification. The decedent and his son attempted a dive in kelp when the father indicated to the son to return to the surface. The decedent became tangled and lost his regulator. Panic developed and he fought with his son. Reports indicate that the inflator hose was not connected to the power inflator and that the victim was wearing a "makeshift" weight belt. Decedent was recovered by other divers, but resuscitation at scene and in hospital was not possible.

DAN Record Numbers: 52 and 66

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: 994.1
Due to: Entrapment (cave)	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

The decedents were a 30-year-old female and a 32-year-old male who entered a cave system despite park regulations and warnings from their instructor. The male had several specialty certifications while the female was making her first dive since certification. After conditions became silty, only

the third member of their team could find the way out. They did not use guide lines. When recovered, both victims were out of air.

DAN Record Number: 56

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Entanglement (rope)	ICD-9-CM: E918.5
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 28-year-old male who had been engaged in salvaging lost anchors near a dam site. His buddy experienced difficulty and surfaced. The recovery team located the decedent suspended in 15 feet of water by a rope caught on his leg. There were cut marks on the rope and his buoyancy compensator buckle had been unlatched.

DAN Record Number: 58

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Entanglement (rope)	ICD-9-CM: E918.5
Due to: Scuba diving	ICD-9-CM: E910.1
Due to: Panic state	ICD-9-CM: 308.0

The decedent was a 47-year-old female who was an inexperienced diver who had accompanied her husband on a quarry dive. This was her first dive in cold water with low visibility. Previous diving had been in tropical water. She immediately began to panic and tried to use her husband's regulator. He inflated her buoyancy compensator, but she could not ascend. He attempted unsuccessfully to rescue her and was in difficulty himself. The husband called for help, and another diver retrieved the decedent. Her regulator was entangled in rope and, with her buoyancy compensator inflated, she was suspended above her regulator and could not reach it.

DAN Record Number: 60

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: 994.1
Due to: Entrapment (cave)	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was an experienced cave diver who was trapped in a cave following a geologic disturbance which blocked the cave exit. One member of the team found an exit and survived.

Case Reports — Drowning Deaths / Insufficient Air

The following group of fatalities died of drowning which appeared to have been primarily the result of a difficulty with air supply. In most cases the air supply was very low or totally exhausted.

DAN Record Number: 6

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Obesity, exogenous	ICD-9-CM: 278.0

The decedent was a 30-year-old male who had been lobster diving in an inlet and had made three long shallow dives (20-30 feet) during the day. An observer witnessed him surface, call for help, then sink. The recovery team located the body 19 hours after the incident. There was no air in the tank or buoyancy compensator. He was wearing a 12-pound weight belt while clad in a bathing suit.

DAN Record Number: 12

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Blood ethanol 22 mg/dL	ICD-9-CM: 305.0
2. Pneumothorax (small)	ICD-9-CM: 860.0

The decedent was an 18-year-old male who was diving with a companion in a sink hole. The pair had made one successful dive. On the second dive the decedent indicated a desire to ascend and the buddy team started for the surface. The decedent did not appear at the surface. The buddy searched for a short time and then called for assistance. The dive recovery team found the decedent on the bottom with the regulator out of his mouth. The investigator's report states that the inflator hose for the buoyancy compensator was leaking air. It did not match the connector on the buoyancy compensator and, therefore, could not be connected. The cause of the decedent's difficulty was not apparent, and the cause of death was drowning. The cylinder contained 200 psi when turned off.

DAN Record Number: 15

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Amphetamines	ICD-9-CM: 980.3

The decedent was a female who was diving from a charter boat in water depth 25-35 feet. She and her companion surfaced about 150 yards from the boat and, on the swim to the boat, the decedent became separated from her buddy. He was in the lead and so he did not realize she was in difficulty. She was recovered from the bottom by the dive master who attempted CPR without success.

The cylinder was reported empty when examined and she was still wearing her 16-pound weight belt. Amphetamines were detected on post mortem examination. It is not conclusive that decedent took amphetamines since metabolites of phenylproponolamine (a common decongestant) may have caused the positive test for amphetamine.

DAN Record Number: 21

Cause of Death

Immediate: Anoxic brain damage	ICD-9-CM: 348.1
Due to: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Coronary atherosclerosis (80 percent LAD)	ICD-9-CM: 414.0

The decedent was a 38-year-old male who had not made a dive since certification one year prior. He surfaced with his buddy after reaching 500 psi on their submersible pressure gauges, and tried to return to their boat. The decedent failed to keep up with his buddy and was recovered from the bottom by the dive guide. He was resuscitated, but died about 48 hours later from anoxic brain damage. The cylinder was empty when tested. The buoyancy compensator was not inflated. Autopsy disclosed 80 percent occlusion of the left anterior descending coronary artery and coronary atherosclerosis.

DAN Record Number: 38

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 59-year-old male who had made a 70 foot dive and was at 35 feet when he signaled to buddy that he had 500 psi of air remaining. While surface swimming to the boat, he developed difficulty and spoke to his buddy before becoming unconscious. Rescue was delayed by heavy sea and CPR by a physician was not successful. The autopsy was consistent with drowning.

DAN Record Number: 43

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Possible insufficient air	ICD-9-CM: E913.2
Due to: Nitrogen narcosis	ICD-9-CM: 293.0
Due to: Scuba diving	ICD-9-CM: E910.1

This decedent was a 41-year-old male who was participating in an advanced class of six students with an instructor to a depth of 120 feet. The dive was stopped by the instructor because of decreasing visibility and the party surfaced. The decedent was missing and his body was located on the bottom 90 minutes later. His cylinder contained 500 psi and the 33-pound weight belt was in place on the victim. The cause of death was drowning.

DAN Record Number: 44

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Pseudoephedrine 0.39 Mg/L	ICD-9-CM: E941.2
2. Nitrogen narcosis	ICD-9-CM: 293.0

The decedent was a 16-year-old male with limited diving experience who was making a 90 foot wreck dive for an advanced level certification. After agreeing to ascend, the buddy team could not find the down line and initiated a free ascent. About 10 feet off the bottom, the decedent came to his buddy with the regulator out of his mouth. The buddy gave the decedent his octopus and signalled to ascend. The decedent did not respond, so the buddy ascended on his own and called for assistance. The body was located in about 5 minutes. The victim's tank had 500 psi remaining and his weight belt was still on.

The pathologist described bubbles in most major vessels and made a diagnosis of air embolism. We have coded the death drowning, for we believe the location and the volume of bubbles suggests post mortem formation. If the decedent died at depth, as seems apparent he did, there would be post mortem off gassing when the body returned to surface pressure. This was probably a drowning, nitrogen narcosis, out of air situation in an immature diver.

Urine toxicology screen was positive for small amounts of amphetamine. This may be due to metabolites of phenylproponoloamine which may have been taken along with the pseudoephedrine which was detected.

Case Reports — Drowning Deaths / Various Causes

DAN Record Number: 13

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 26-year-old male and an uncertified diver. The decedent had been diving with a certified buddy in a high altitude lake. The decedent had trouble equalizing his ears on several previous dives. After descending and ascending several times, both divers were able to descend to approximately 15 feet. The victim signalled "OK" to his buddy who then turned away and swam a short distance. The certified buddy turned around and noticed his partner on the lake floor with the regulator out of the mouth and mask removed from the face. The victim was still wearing his 32-pound weight belt. The buddy brought the decedent to the surface and called for help. The tank pressure was 2,000 psi when measured after the accident.

DAN Record Number: 24

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Hypothermia	ICD-9-CM: E901.0

The decedent was a male who had been diving offshore with a buddy. They had and drifted away from their boat in the current. They reached a buoy after several hours in the water and had clung to it overnight. The decedent was not wearing a wet suit, while the survivor was. The survivor described classic hypothermia symptoms developing in the decedent who died shortly before being rescued.

DAN Record Number: 31

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 43-year-old male who was diving alone from a rocky shore in an area of strong current and rough surf using rented gear. A witness observed that the decedent was in distress. Lifeguards were about one-half mile away and by the time they could be summoned and reached the scene the decedent was floating face down in the water. He had abandoned his gear and weight belt for unknown reasons. The dive gear was lost at sea, but the weight belt was found at a later date.

DAN Record Number: 45

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a male, and an untrained diver. The decedent was using borrowed gear and collecting lobsters in the company of two certified lobster divers. He was diving alone and was observed to surface, call for help and then submerge. Witnesses went to his assistance immediately and found him out of his scuba gear on the bottom, but still wearing his 7-pound weight belt and one fin.

DAN Record Number: 48

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Nitrogen narcosis	ICD-9-CM: 293.0
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 22-year-old female making a deep dive for her advanced open water certification at 100 feet. She was missing at the 15 foot stop and was recovered by the two dive instructors. She had 1,600 psi remaining and her 22-pound weight belt was in place. CPR restored a perfusing rhythm but the decedent remained comatose. She was recompressed, but died in the chamber about four hours after the event. Autopsy is consistent with drowning.

DAN Record Number: 49

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1
Due to: Panic state	ICD-9-CM: 308.0
Due to: Insufficient air	ICD-9-CM: E913.2

The decedent was a male, and an uncertified diver. While two divers did a shore entry dive to about 15 feet, their friend sat on the beach and watched. The inexperienced member of the dive team left the water and lent his gear to his uncertified friend, unknown to the other buddy. The uncertified diver was observed to be in distress on the surface a short time later. The buddy who had lent the gear swam to the panicked victim and attempted to render assistance; however, the decedent had ditched all gear except his weight belt and sank to the ocean floor. The search team located the body in one hour. The tank was out of air. The cause of death was drowning.

DAN Record Number: 55

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 31-year-old female who was diving in a quarry with 46°F water and limited visibility. She was diving with an unfamiliar dive buddy. They made an unplanned ascent due to cold and lost contact with each other. The decedent did not surface and was found on the bottom some time later. One fin was missing and her buoyancy compensator was not inflated. There is no mention of the weight belt in the record. When tested, the tank had 2,000 psi of air remaining.

DAN Record Number: 57

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 31-year-old female who was receiving instruction in open water diving and surf entry. She had made one previous similar dive and had experienced an episode of hyperventilation

in the pool. She was the only student with the instructor. They attempted to swim under the surf, surfaced, and switched from regulators to snorkels. A large wave caught the decedent and she aspirated sea water. She was rescued with difficulty by the instructor, who initiated CPR. The autopsy was consistent with drowning.

DAN Record Number: 61

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Cocaine 0.05 Mg/L	ICD-9-CM: E980.4

The decedent was a member of a three member buddy team. Another buddy developed difficulty and the other two escorted him to surface, however, the decedent did not indicate any difficulty and after the diver in trouble was rescued, the decedent was found floating face down in water with regulator out. The cocaine levels are significant and it is possible that a cardiac dysrhythmia occurred especially with the synergistic effect between catecholamines and cocaine. The decedent quite likely had catecholamine release during the excitement of taking care of the other diver.

Table 10.2 Contributing Factors to Drowning

Contributing Factors	Number of Divers
Insufficient air	19
Buoyancy Problem*	15
Entrapment	11
Cardiovasular	8
Alcohol / drugs	5
Panic state	5
Nitrogen narcosis	4
Air embolism	3
Hypothermia	1
Obesity	1
Rapid ascent	1

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

The majority of the drowning cases were associated with running out of air. Sometimes this was due to the situation as entrapment in a cave, a wreck, under ice or being lost. Many cases appear to have simply run out of air unexpectedly, and were unable to perform self-rescue. There were several inexperienced divers in this category.

There were other drowning victims who had air available in their cylinders, but did not use it. There were also many cases where the cylinder pressure was not reported. There were six cases in which

alcohol or other drugs of abuse were found in significant blood concentration. The number of autopsies done without toxicology studies is not known, but there were some.

The contributing factors to drowning which may not be under the divers control are the boat accidents, trauma, and possibly contaminated air. All of the other factors can be eliminated.

Trauma
There was one death due to multiple trauma.

Case Reports — Trauma

DAN Record Number: 67
Cause of Death

Immediate: Multiple trauma	ICD-9-CM: 799.9
Due to: Struck by boat	ICD-9-CM: E838.5
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 17-year-old male who was diving in about 30 feet with three friends. Two members of the group were certified to dive. The victim and another diver had been diving before but were not certified. The decedent surfaced after approximately 30 minutes and was hit by a boat. None of the divers towed a dive flag. The investigator suggests the possibility that the victim surfaced because he could not control his buoyancy. The 5'4" 150-pound youth dove in his swim suit and was using an aluminum tank, which was reportedly providing three to four pounds of positive buoyancy at the time of the accident. The cause of death was multiple traumatic lacerations due to the vessel propeller.

Incomplete Autopsy Reports
There were four cases of unclassified cause of death following autopsy (DAN # 10, 14, 42, 54). One of these cases is the subject of criminal investigation and another was a military autopsy. The cause of death for both cases has been withheld by the authorities. There was one case with a non-diagnostic autopsy due to delayed recovery of the body. The fourth case was autopsied, but the complete report was not released by the jurisdiction involved and the medical examiner's final determination was unknown cause of death.

DAN Record Number: 10
Cause of Death

Immediate: Instantaneous death, cause undetermined	ICD-9-CM: 994.1

The decedent was a 37-year-old male who died while attempting to make a shore entry during an advanced class night dive. The surf was unexpectedly high so the group attempted to swim over to a calmer zone. The instructor easily crossed the coral, while the two students experienced some difficulty. The instructor, giving directions to the buddy team, was in verbal and visual contact with the student at all times. After one student cleared the surf zone, the instructor noted the other student floating passively face down, regulator in his mouth.

The entire autopsy report is not available but circumstances and limited autopsy information are consistent with drowning. The pathologist gave no cause of death and noted an "abnormality" of the left anterior descending coronary artery.

DAN Record Number: 14

Cause of Death

Immediate: Cause not discovered	ICD-9-CM: 798.2
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Nitrogen narcosis	ICD-9-CM: 293.0

The decedent was a 43-year-old male who was diving at a depth of 230 feet on an offshore wreck and gave evidence of some narcosis as witnessed by buddy. On ascent the decedent became unconscious for unknown reasons and was too heavily weighted for his companions to bring him to the surface. The body was subsequently lost and was recovered five months later by the crew of a scallop trawler. The condition of the body did not allow establishment of cause of death at autopsy.

DAN Record Number: 42

Cause of Death

Immediate: Pending	ICD-9-CM: 798.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Scuba diving	ICD-9-CM: E910.1

This case is under investigation by state police to determine whether or not death was accidental. No cause of death as yet established.

No Autopsies

An autopsy was not done in nine instances (DAN # 26, 27, 29, 30, 39, 40, 47, 53, 62) for various reasons. There were an additional five cases (DAN # 7, 28, 35, 36, 41) in which no body was located. Detailed investigations, family and witnesses information are very important in these cases since limited medical conclusions can be drawn without an autopsy.

Main sources of information in these 14 cases included investigation reports, local contacts, witness and family interviews and news clips. When used as a sole source of information, news clips generally do not provide complete information.

DAN Record Number: 26

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a male who was diving with his buddy in tropical waters. He experienced difficulty while surface swimming to the boat. The buddy managed to reach the boat, but the decedent did not and drowned. Witnesses reported that the victim surfaced, called for assistance, then submerged. When recovered, the tank was empty, contained sea water and the decedent was still wearing his weight belt. Fellow divers reported the sea state was "rough as hell."

DAN Record Number: 27

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Scuba diving	ICD-9-CM: E910.1

Other significant conditions contributing to death but not resulting in underlying cause

1. Depressive disorder	ICD-9-CM: 311
2. Nitrogen narcosis	ICD-9-CM: 293.0

The decedent was a female who had been on a three week diving trip to a tropical area. The investigator's report states that she had made many dives and was taking medications for depression. Reports also state that she "drank heavily" during her stay. She made a dive with a guide to 120 feet and then left the guide and went to 250 feet. She was in the act of taking off her scuba gear when the guide forced her to surface. She was alive at the surface, but died within 15 minutes. No autopsy was performed.

DAN Record Numbers: 29 and 30

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Entrapment (cave)	ICD-9-CM: E918.2
Due to: Scuba diving	ICD-9-CM: E910.1

The decedents were a husband and wife buddy team who died while attempting a cave dive in Missouri. The husband was reported to be an experienced diver, having "logged over 600 dives," while his wife was new to diving. Neither diver was trained in cave diving. They entered the system with no guidelines to the surface. The husband carried the main light and the wife carried the backup light. Reportedly, visibility is generally about 30 to 40 feet, but recent rains and flash floods had dropped the visibility to less than five feet. Although this cave system is not complicated, it took the recovery team over one day to find the bodies which were located more than 300 feet into the system and about 10 feet off the permanent line. The husband's inflator hose was disconnected. When tested, it caused the buoyancy compensator to continually inflate.

DAN Record Numbers: 39 and 40

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Entrapment (cave)	ICD-9-CM: E918.2
Due to: Entanglement (line)	ICD-9-CM: E918.5
Due to: Scuba diving	ICD-9-CM: E910.1

The decedents were a buddy team, one 42-years-old and the other 66-years-old, who became entangled in their guideline while attempting to traverse a 300 foot long sump. Neither diver had cave diving training although one had extensive hard hat diving experience and had been involved in dry cave exploration for a long time. Both divers had air remaining in their tanks.

DAN Record Number: 47

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to: Insufficient air	ICD-9-CM: E913.2
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 35-year-old male making his first dive in over a year. He and his buddy surfaced and swam through kelp to return to the boat. After a few minutes, the decedent apparently lost consciousness. His tank contained 55 psi when examined. The decedent was not autopsied due to his "religion." The medical examiner certified death as "complications of scuba diving accident." Evidence suggests near drowning and delayed death due to anoxic brain damage after prolonged cardiac arrest.

DAN Record Number: 53

Cause of Death

Immediate: Instantaneous death, cause undiscovered	ICD-9-CM: 798.1

The decedent was a 64-year-old female and an experienced diver who became separated from her husband on a moderately strenuous dive in tropical waters. She was discovered dead on the surface after all divers returned to the boat. She had no past or current medical problems, however, she had a history of DCS. Although an autopsy was requested, foreign officials did not perform one.

DAN Record Number: 62

Cause of Death

Immediate: Drowning	ICD-9-CM: 994.1
Due to : Scuba diving (non-recreation)	ICD-9-CM: E910.3

Other significant conditions contributing to death but not resulting in underlying cause

1. Blood alcohol 60 mg/dL	ICD-9-CM: 305.0
2. Ethanol dependence syndrome	ICD-9-CM: 303.0

The decedent was a male who was attempting to recover a sunken lobster boat. He was drinking beer at the time of the dive and had an alleged history of drug and alcohol abuse. He was wearing a 40-pound weight belt with a wet suit. Unknown difficulty developed at the surface and he sank. There was no standby diver and the body was recovered by local recreational divers about two hours later.

DAN Record Number: 7

Cause of Death

Immediate: Death, unspecified cause	ICD-9-CM: 799.9
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 28-year-old male who aborted the first dive of the day because of equalization problems. He also had a history of asthma, and was reportedly seasick and very cold. The decedent and his two buddies attempted another dive. At 10 feet, the members all signaled OK and descended. The victim was not seen again. One of the two wet suits tops he was wearing was found 8.5 miles from the dive site.

DAN Record Number: 28

Cause of Death

Immediate: Death, unspecified cause	ICD-9-CM: 799.9
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 49-year-old male who surfaced after speareing a fish, indicated to his friend on the boat that he needed assistance, then submerged. The friend dove in without any gear and unsuccessfully attempted to pull the diver up. A diver from another boat who was in the water attempted to reach the decedent, but was low on air. He observed that the victim stopped kicking and that no bubbles came from the regulator. Searchers were not able to locate the body. Reportedly there was a thermocline at 80 feet and a slight current. Visibility above the thermocline was 80 feet plus, but visibility dropped to five feet below the thermocline. The decedent had allegedly been drinking rum prior to the dive.

DAN Record Number: 35

Cause of Death

Immediate: Death, unspecified cause	ICD-9-CM: 799.9
Due to: Scuba diving	ICD-9-CM: E910.1

The decedent was a 33-year-old male who disappeared while solo diving. The body was never recovered. He held an advanced certification but no other information is available.

DAN Record Number: 36

Cause of Death

Immediate: Death, unspecified cause	ICD-9-CM: 799.9

Other significant conditions contributing to death but not resulting in underlying cause

1. Scuba diving	ICD-9-CM: E910.1

The decedent was a 28-year-old female who disappeared while diving in an area of strong current. No other information is available.

DAN Record Number: 41

Cause of Death

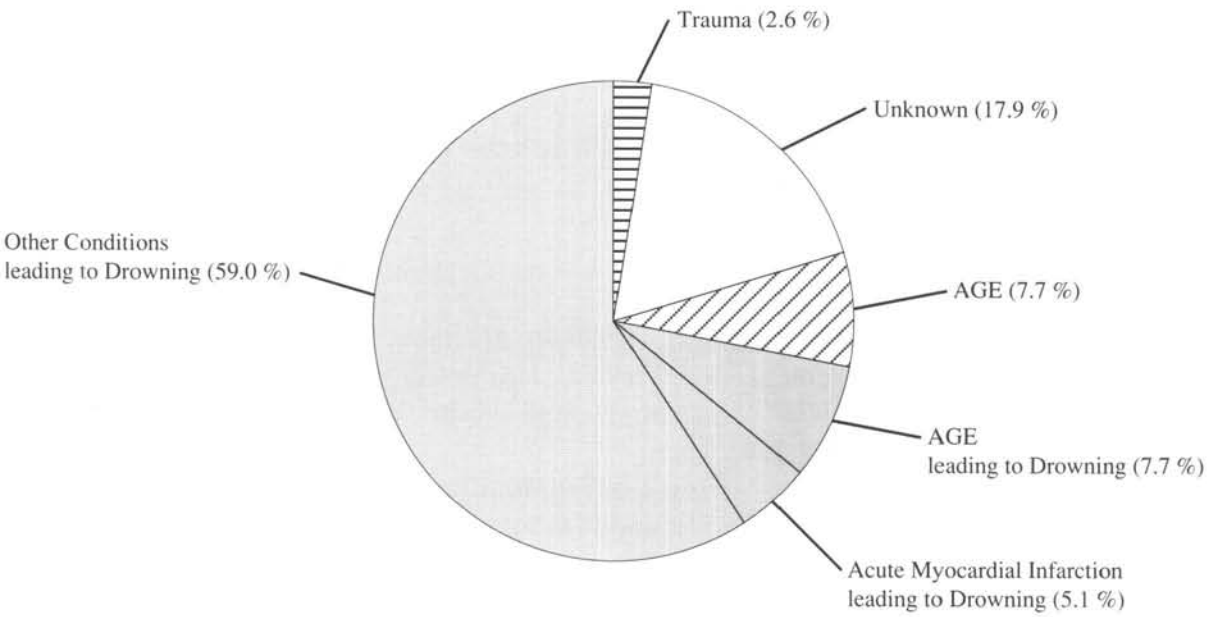
Immediate: Death, unspecified cause ICD-9-CM: 799.9

The decedent was a 32-year-old male who disappeared while solo diving. He planned a dive to 300 feet, well beyond established recreation depth limit of 130 feet and even beyond the accepted limits for commercial and technical diving on air. Locals saw him on the beach with multiple tank harnesses. His body was never located. Reportedly, this individual was a graduate of a commercial diving school and an active instructor.

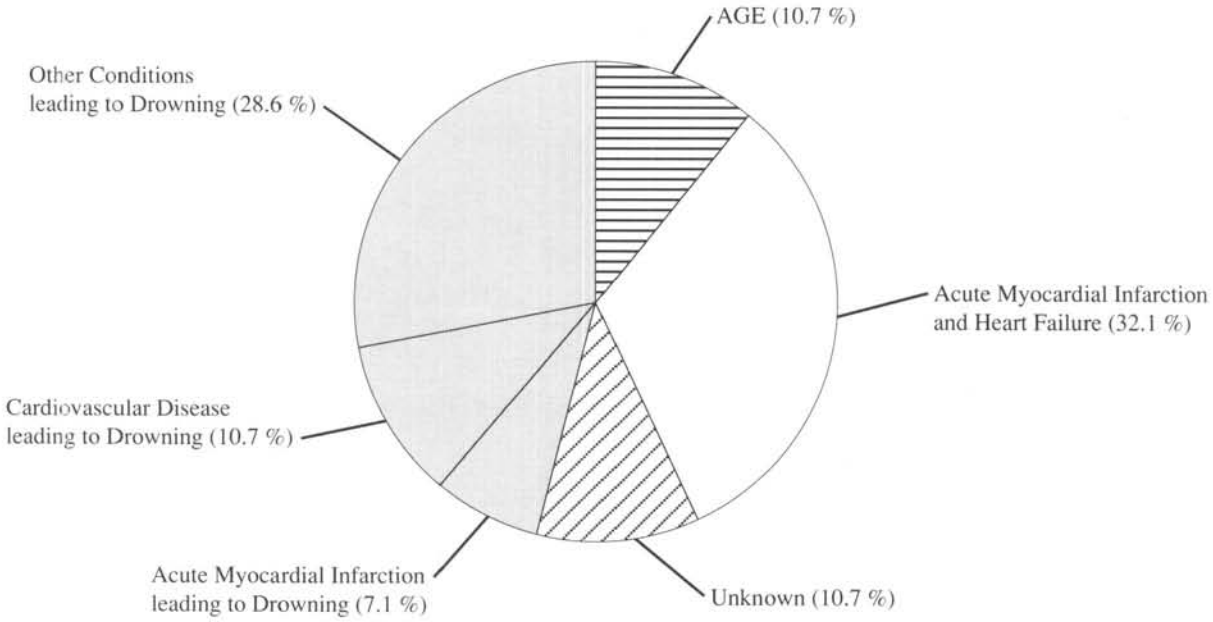
References

1. *International Classification of Diseases — Clinical Modification*, (9th Revision), U.S. Department of Health and Human Services, Public Health Services, Health Care Financing and Administration.
2. Denfield, S.W., Garson, A. Jr. (1990), Sudden death in children and young adults, *Pediatric Clinics of North America,* 37:1, 215-231.
3. Bachrach, A.J. and G. Egstrom (1987) *Stress and Performance in Diving,* Best Pub. Co., San Pedro.
4. Bove, A.F. (1990). Cardiovascular Disorders and Diving. In *Diving Medicine,* (ed. A.F. Bove and J.C. Davis), pp. 239. W.B. Saunders, Philadelphia.

Graph 10.3 Deaths Under Age 40



Graph 10.4 Deaths Over Age 40



1991 Case Report Index

DAN DIVE ACCIDENT REPORTING FORM

BOX 3823 • DUKE UNIVERSITY MEDICAL CENTER
DURHAM, NORTH CAROLINA 27710
Information Mon.–Fri. 9–5 (E.T.) (919) 684–2948
Emergencies Only (919) 684–8111

DATE & TIME OF ACCIDENT
MONTH/DAY/YEAR
Time _____ AM PM

IS THIS A FATALITY REPORT?
☐ YES ☐ NO

For DAN Office Use Only
CASE
SEVERITY CODE
BMI

1. PATIENT NAME LAST FIRST MI

2. OCCUPATION

3. ADDRESS STREET CITY ST ZIP

4. PATIENT PHONE (HOME) - -

5. PATIENT PHONE (WORK) - -

6. COUNTRY (IF NOT USA)

7. AGE YRS

8. SEX M or F

9. HEIGHT FT IN

10. WEIGHT LBS.

11. CERTIFYING AGENCY
A - PADI
B - NAUI
C - NASDS
D - YMCA
E - SSI
F - Other
G - None

12. CERTIFICATION LEVEL
A - Basic
B - Open Water
C - Advanced
D - Divemaster
E - Instructor
F - Commercial
G - Other
H - None
I - Student

13. DAN MEMBER?
Y - Yes
N - No

14. YEARS DIVING YEARS MONTHS

15. NUMBER OF DIVES MADE Total; Previous 12 months

16. PREVIOUS DIVE ACCIDENTS
A - Possible DCS
B - DCS
C - AGE
D - Pul. barotrauma
E - None

17. CURRENT MEDICATIONS
Y or N
Prescription
Non-prescription
List _____

18. CIGARETTE USE
A - Presently
B - In past
C - Never
Years Smoking
Packs per day

19. PREVIOUS MAJOR ILLNESSES/ SURGERY
(Provide up to 3 responses)
A - Chest-lung
B - Asthma
C - Chest-heart
D - Gastrointestinal/Abdomen
E - Brain
F - Spine/Back
G - Limb or joint of DCS site
H - Circulation/Blood
I - Neurologic/Nervous system
J - Muscle/Skeleton system
K - Eye
L - Mental/Emotional
M - Other _____
N - None

Past:
A - 2-6 months
B - 7-12 months
C - 1-3 years
D - 2-5 years
E - 6+ years

List and describe specific problems:

20. CURRENT HEALTH PROBLEMS WITHIN PREVIOUS 2 MONTH
(Provide up to 3 responses)
A - Chest-lung
B - Asthma
C - Chest-heart
D - Gastrointestinal/Abdomen
E - Brain
F - Spine/Back
G - Limb or joint of DCS site
H - Circulation/Blood
I - Neurologic/Nervous system
J - Muscle/Skeleton system
K - Eye
L - Mental/Emotional
M - Other _____
N - None

List and describe specific problems or additional current medications

PLEASE ATTACH SEPARATE SHEET FOR ADDITIONAL INFORMATION OR NARRATIVE.

I understand that the information in this form will be used for research purposes only, and that all personal information will be kept strictly **confidential**. I also understand that the Divers Alert Network may need to contact me in the future for clarification of information provided on this form.

_____
Patient Signature

DIVE ACCIDENT

21. PURPOSE OF DIVE
- A - Pleasure
- B - Work/Labor

22. DIVE ACTIVITY (up to 2 responses)
- A - Wreck
- B - Cave
- C - Night
- D - Photography
- E - Under Instruction
- F - Providing Instruction
- G - Spearfishing/ Game collecting
- H - Sightseeing

23. ENVIRONMENT
- A - Freshwater
- B - Saltwater

24. ALTITUDE OF DIVE
- A - Sea Level
- B - > Sea Level but < 1000 ft.
- C - > 1000 ft.

25. Was this dive or dive series typical of your normal type of diving?
- Y - Yes
- N - No

IF NO, Explain _____

26. DIVER'S PERCEPTION OF TEMPERATURE
- A - Cold
- B - Hot
- C - Comfortable

27. CURRENT STRENGTH
- A - Strong
- B - Moderate
- C - Mild
- D - None

28. AIR SUPPLY
- A - Scuba Air
- B - Surface Supply Air
- C - Mixed gas
- D - None/Breath-hold dive

29. AIR CONSUMPTION
- A - Ran low
- B - Out of air
- C - Not a problem
- D - Buddy breathing (not octopus)

30. BUOYANCY PROBLEM
- Y - Yes
- N - No

31. RAPID ASCENT
- Y - Yes
- N - No

32. WITHIN LIMITS-Y or N
- Tables (which table _____)
- or
- Computer (type _____)

33. TYPE OF SUIT
- A - Wet
- B - Partial Wet
- C - Dry
- D - Lycra
- E - Swim

34. EQUIPMENT USED ON DIVE: (please check all that apply)
- Depth gauge
- Timing device/watch
- Buoyancy vest
- BC Inflator hose in use
- Decompression computer

35. EQUIPMENT MALFUNCTION:
- A - None
- B - Regulator
- C - BC Vest
- D - Weight belt
- E - Dry suit
- F - DC Computer
- G - Inflator hose
- H - Contaminated air supply
- I - Equipment was not familiar to you.
- J - Other

Reason: _____

36. TYPE OF DIVE
- Y - Yes
- N - No
- Single
- Repetitive

37. WOMEN, PLEASE RESPOND (up to 2 responses)

When the accident occurred, were you:
- A - Menstruating
- B - On birth control medication
- C - Pregnant
- D - None of the above

38. DIVE LOCATION:

State, Province, or Island: _____

Country or nearest country: _____

39. How long ago was your last Dive Trip/Series?

Circle one: Days Weeks Months

40. STRENUOUS EXCERCISE
- Y - Yes
- N - No
- 24 hours predive
- During dive
- 6 hours postdive

41. PREDIVE HEALTH
- A - Nausea/ vomiting
- B - Hangover
- C - Diarrhea
- D - Other
- E - No Problem

42. ALCOHOL

Please check:

Number of drinks, beers, or wine
- None
- Night Before
- Predive
- Between Dives
- Post Dive

43. RECREATIONAL DRUG USE

Prior to, between, or after dive
- Y - Yes
- N - No

44. Do you consider yourself physically fit?
- Y - Yes
- N - No

Do you excercise on a weekly basis? (Y or N)

Days per week

45. FATIGUE OR LACK OF SLEEP PRIOR TO DIVE?
- Y - Yes
- N - No

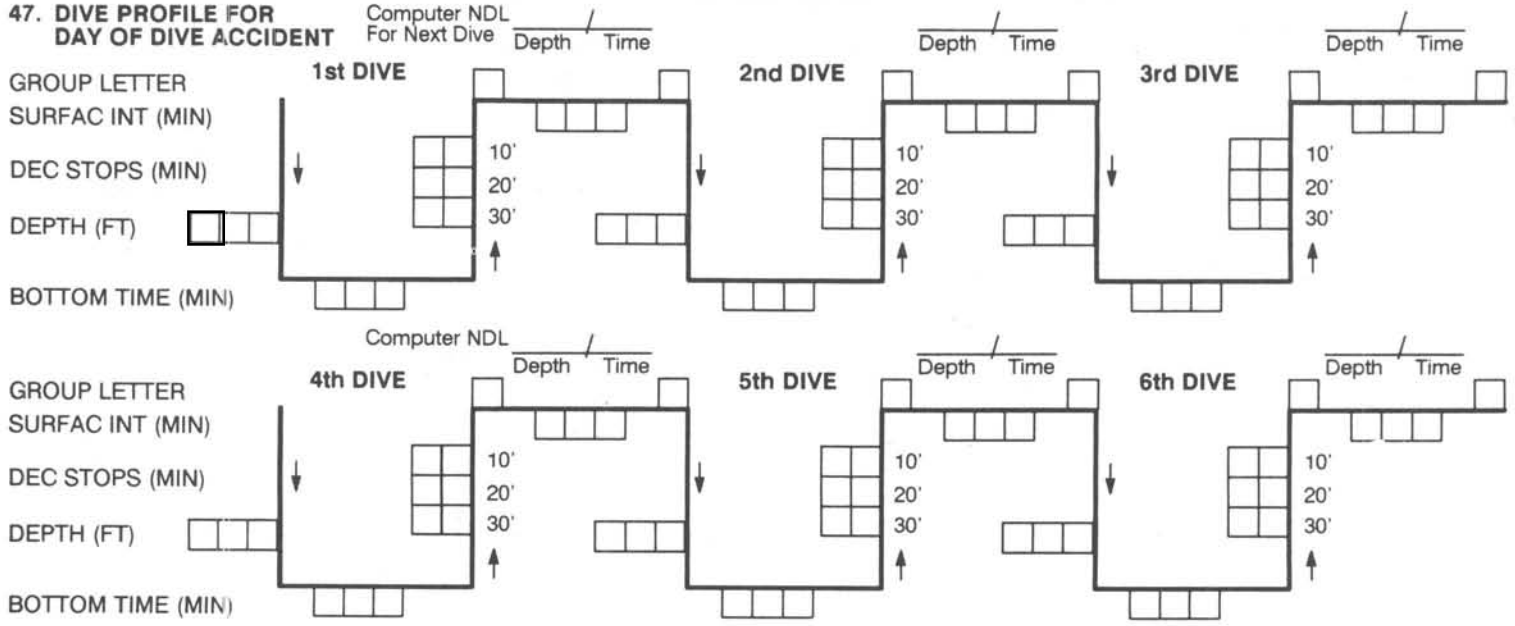
46. DIVE SERIES

Please fill in all that apply up to and including your last dive. If you skipped a day please leave that day blank.

	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7
Total # of dives							
Any night dive? (How many)							
Any symptoms? (Yor N)							
A - All no stop dive(s) B - Any safety stop C - Any dive requiring decompression stops							
A - Multilevel (time divided) B - Square							
Deepest Dive (ft.)							

DIVE ACCIDENT (cont.)

47. DIVE PROFILE FOR DAY OF DIVE ACCIDENT



PRE-CHAMBER INFORMATION

48. INITIAL CONTACT WAS:

- A - DAN Emergency
- B - DAN Non-emergency
- C - Hospital emergency room
- D - Emergency medical service
- E - US Coast Guard
- F - Physician
- G - Dive instructor/shop
- H - Other: _____

49. Total delay from symptom onset to contacting DAN or other medical help:

HOURS or DAYS

50. FLYING OR INCREASED ELEVATION AFTER DIVING AND PRIOR TO TREATMENT?

- A - Commercial airliner
- B - Unpressurized aircraft
- C - Med Evac Flight
- D - Mountain elevation
- E - Does not apply

Hours post dive (flew or went into elevation)

elevation (in feet)

51. SIGNS & SYMPTONS

1st Symptom / 2nd Symptom / 3rd Symptom / 4th Symptom / 5th Symptom / 6th Symptom

- A - Pain
- B - Rash
- C - Itching
- D - Weakness
- E - Numbness/Tingling
- F - Dizziness/Vertigo
- G - Semi-consciousness
- H - Unconsciousness
- I - Restlessness
- J - Extreme fatigue
- K - Visual disturbance
- L - Speech disturbance
- M - **Headache**
- N - Paralysis
- O - Difficulty breathing
- P - Nausea/Vomiting
- Q - Hemoptosis/coughing blood from lungs
- R - Muscle twitching
- S - Convulsions
- T - Hearing loss
- U - Ringing ears
- V - Decreased skin sensation
- W - Bladder problem
- X - Bowel problem
- Y - Personality change
- Z - Difficulty walking/ standing
- 1 - Reflex change
- 2 - Other: _____

52. LOCATION: Block A = location of symptom
Then please check (✓)
L = Left R = Right B = Bilateral/Both Sides

A L R B

1st Symptom / 2nd Symptom / 3rd Symptom / 4th Symptom / 5th Symptom / 6th Symptom

- A - Head
- B - Face
- C - Sinus
- D - Eyes
- E - Ears
- F - Neck
- G - Shoulder
- H - Entire arm
- I - Upper arm
- J - Elbow
- K - Forearm
- L - Wrist
- M - Hand
- N - Fingers
- O - Chest
- P - Back
- Q - Upper back
- R - Lower back
- S - Abdomen
- T - Buttock
- U - Groin
- V - Hip
- W - Entire leg
- X - Thigh
- Y - Knee
- Z - Calf
- 1 - Shin
- 2 - Ankle
- 3 - Foot
- 4 - Toes
- 5 - Trunk
- 6 - Generalized
- 7 - Other: _____

53. SYMPTOM ONSET:

	HOURS	MINUTES	or	BEFORE SURFACING FROM DIVE
1st Symptom				
2nd Symptom				
3rd Symptom				
4th Symptom				
5th Symptom				●
6th Symptom				

54. ANY OF THE SYMPTOMS FROM #51 PRIOR TO THE LAST DIVE?

Y - Yes
N - No

If yes, which symptoms?

1st / 2nd / 3rd / 4th / 5th / 6th

Other

Explain: _____

55. FIRST AID ADMINISTERED BEFORE HOSPITAL OR CHAMBER HELP WAS RECEIVED?

Y - Yes
N - No

- Oxygen
- Aspirin
- Oral fluids
- Head down position/ Trendelenburg

If oxygen was received was delivery by:

- A - Demand valve
- B - Freeflow valve
- C - Don't know

PRE-CHAMBER INFORMATION (cont.)

56. HOSPITAL TREATMENT ADMINISTERED

(Please check all that apply):

- ☐ None
- ☐ Oral fluids
- ☐ IV fluids
- ☐ Oxygen
- ☐ Steroids
- ☐ Anticoagulant
- ☐ Aspirin
- ☐ Other medication

_____

_____

57. RELIEF BEFORE CHAMBER TREATMENT?

☐
A - Complete
B - Partial
C - Temporary
D - None

59. PRE-CHAMBER RELIEF OCCURRED:

☐
A - Without first aid or medical care
B - Following first aid
C - Following pre-chamber hospital care
D - No relief occurred

58. IF ANY RELIEF OCCURRED, WHICH SYMPTOMS FROM #51 ABOVE?

(Please check):

1st ☐
2nd ☐
3rd ☐
4th ☐
5th ☐
6th ☐

CHAMBER TREATMENT

60. CHAMBER TREATMENT FACILITY LOCATION

CITY

STATE COUNTRY

Date & Time of Treatment

MONTH/DAY/YEAR

Time _____ AM PM

Name of hyperbaric facility:

Treating doctor

Form Completed By

_____

61. TYPE OF CHAMBER
(please check)

Initial Treatment	Retreatment Chamber
☐ Monoplace	☐ Monoplace
☐ Dualplace	☐ Dualplace
☐ Multiplace	☐ Multiplace
☐ No chamber treatment given	

62. TOTAL DELAY FROM SYMPTOM ONSET TO RECOMPRESSION

HOURS ☐ or DAYS ☐

63. INITIAL TREATMENT

☐
A - USN TT4
B - USN TT5
C - USN TT6
D - USN TT6A
E - HART Protocol
F - KINDWALL Protocol
G - 45 fsw 90 min
H - 33 fsw 120 min
I - Other

_____

_____

64. TABLE EXTENSIONS REQUIRED?

☐
Y - Yes
N - No

65. RELIEF AFTER INITIAL TREATMENT OF SYMPTOMS FROM # 51?

1st ☐
2nd ☐
3rd ☐
4th ☐
5th ☐
6th ☐

Please indicate:
A - Complete
B - Partial
C - Temporary
D - None

66. RETREATMENT GIVEN
(Provide up to 3 responses)

TABLE	NUMBER OF TREATMENTS
☐	☐
☐	☐
☐	☐

A - USN TT4
B - USN TT5
C - USN TT6
D - USN TT6A
E - HART Protocol
F - KINDWALL Protocol
G - 45 fsw 90 min
H - 33 fsw 120 min
I - Other

_____

67. RELIEF AFTER HYPERBARIC THERAPY COMPLETED?

☐
A - Complete
B - Partial
C - Temporary
D - Hyperbaric therapy not completed
E - None

68. RESIDUAL SYMPTOMS AFTER HYPERBARIC THERAPY COMPLETED?

☐
A - Pain only
B - Neurologic
C - Hyperbaric therapy not completed
D - None

69. DURATION OF RESIDUAL SYMPTOMS

(Circle one)

☐
DAYS
WEEKS
MONTHS

70. FINAL DIAGNOSIS:

☐
A - DCS I
B - DCS II
C - Air Embolism
D - Pulmonary Barotrauma
O - Other:

_____

_____

_____

I WOULD LIKE TO RECEIVE DAN INFORMATION.

☐
Y - Yes
N - No

DIVERS ALERT NETWORK
FATALITY WORKSHEET

DIVER PROFILE

Name of deceased _____ Date of death _____
Time of death _____ Birth date _____ Age _____ Race _____
Occupation _____ Marital status _____
Sex _____ Height _____ Weight _____ Certified Y / N Years diving _____
Certification level _____ Total number of dives made _____ Dives in last 12 months _____
*General experience level _____ *Experience level within activity _____

DIVE CONDITIONS

Location _____ Entry: shore , private boat , charter boat
Altitude: less than 1000ft , between 1000ft and 3000ft , more than 3000ft Water environment: salt , fresh
Water temp _____ Water depth _____ Seas: calm , moderate , rough Visibility(ft) _____
Amount of current: none , mild , moderate , strong Amount of surge: none , mild , moderate , strong
Weather conditions _____ Bottom type _____
Diver's first time at this location Y / N Type of exposure suit _____ Tender Y / N
Number in dive party _____ Buddy Y / N Number in buddy team _____ Buddy separation Y / N
Dive activity _____ Specialty dive Y / N If yes, specialty certified Y / N

DIVER HEALTH

Panic Y / N Physically fit Y / N *Pre dive health (see back) _____ *Mental status (see back) _____
Previous dive accidents _____ Previous major illness _____
Undiagnosed health problems _____ Current health problems _____
Prescription medications _____ Non-prescription medications _____
At the time of the accident,was diver influenced by: Fatigue Y / N Alcohol Y / N Recreational drugs Y / N

EQUIPMENT AND OTHER DIVE PROBLEMS

Equipment problems Y / N Problem 1 _____ Problem 2 _____
Air supply: scuba , surface supplied air , mixed gas , breath hold diving , bad air supply Rapid ascent Y / N
Air Consumption: low on air , out of air , not a problem , buddy breathing/sharing air Infrequent Diver Y / N
Nitrogen narcosis Y / N Lost Y / N Trapped Y / N Entangled Y / N Buoyancy problem Y / N
Weight belt _____ lbs Dropped Y / N Familiar with equipment Y / N

DIVE PROFILE

Single dive Y / N / Bounce Decompression dive Y / N Last dive series _____ Using a computer Y / N
Dive# 1: Depth: _____ (ft) Bottom time: _____ (min) Surface interval: _____ (hrs & min)
Dive# 2: Depth: _____ (ft) Bottom time: _____ (min) Surface interval: _____ (hrs & min)
Dive# 3: Depth: _____ (ft) Bottom time: _____ (min) Surface interval: _____ (hrs & min)

RECOVERY AND FIRST AID

Was event witnessed? Y / N How long into dive did the problem occur? _____ (min) What depth _____ (ft)
Where problem occurred: surface-pre dive, descent, bottom, ascent, surface-post dive Signs diver in distress Y / N
Immediate search Y / N / N/A If no: After _____ (days) _____ (hours) _____ (minutes)
Was body recovered Y / N If yes: After _____ (days) _____ (hours) _____ (minutes)
CPR done Y / N / N/A Was oxygen available at dive site Y / N Was oxygen administered Y / N / N/A
USCG assistance Y/N Medivac Y/N Place death registered _____

REPORT OF INVESTIGATION BY MEDICAL EXAMINER

Probable cause of death _____ Due to _____
Due to _____ Contributory condition _____
Manner of death: natural, accident, homicide, suicide, pending Autopsy done Y / N If yes, please attach copy.

*Instructions on last page of this worksheet.

To report fatalities or for information on fatalities, call (919)684-2948.
Please return a copy of the worksheet to: Fatality Research, DAN, Suite 1300, 3101 Petty Rd., Durham, NC 27707

DAN Case Number: _____ ME Case Number _____ IR Case Number _____
First Contact: _____ Source 1 _____ Source 2 _____ Source 3 _____

ACCIDENT SCENARIO (use additional sheets if necessary): ....

FATALITY WORKSHEET INSTRUCTIONS AND KEY

Please answer all questions to the best of your knowledge. If you do not know the appropriate response, enter '?' into the blank. Responses for questions not listed below are self-explanatory.

General and Activity Experience level: (includes certification dives)
- 1 = Non Certified
- 2 = Novice (0-5 dives)
- 3 = Inexperienced (6-20 dives)
- 4 = Intermediate (21-40 dives)
- 5 = Advanced (41-60 dives)
- 6 = Experienced (61+ dives)

Pre-dive health:
- 1 = Nausea/Vomiting
- 2 = Hangover
- 3 = Pre/Post dive alcohol
- 4 = Diarrhea
- 5 = No problem
- 6 = Other - please list

Pre-dive mental status:
- 1 = No problem
- 2 = Stressed
- 3 = Anxious
- 4 = Quiet
- 5 = Talkative
- 6 = Agitated
- 7 = Other - please list

Appendix C DAN Diagnosis Coding for Disease Severity

CODE = 0		ASYMPTOMATIC	
CODE = 1	DCS-I	LOCATION*	SIDE
PAIN		G, H, I, J, K, L, M, N, U, V, W, X, Y, Z.	ANY
RASH		ANY	ANY
ITCHING		ANY	ANY
CODE = 2	DCS-II	LOCATION*	SIDE
PAIN		F, D, Q, R, S, T, 4, 5.	ANY
NUMB/TINGLE		ANY	L/R
RESTLESS		ANY	ANY
HEADACHE		ANY	ANY
SKIN-SENSATION		ANY	L/R
MUSCLE-TWITCH		ANY	ANY
CODE = 3	DCS-II	LOCATION*	SIDE
RINGING EARS		ANY	ANY
DIZZINESS		ANY	ANY
PAIN		O	ANY
FATIGUE		ANY	ANY
REFLEX		ANY	ANY
CODE = 4	DCS-II	LOCATION	SIDE
WEAKNESS		ANY	L/R
NUMB/TINGLE		ANY	BOTH
BREATHING		ANY	ANY
NAS/VOMIT		ANY	ANY
HEARING LOSS		ANY	ANY
SKIN-SENSATION		ANY	BOTH
PERSONALITY		ANY	ANY
WALK/STANDING		ANY	ANY
CODE = 5	DCS-II	LOCATION	SIDE
VISUAL-DIS		ANY	ANY
SPEECH-DIS		ANY	ANY
WEAKNESS		ANY	BOTH
PARALYSIS		ANY	BOTH
BLADDER		ANY	ANY
BOWEL		ANY	ANY
CODE =6	A-G-E	LOCATION	SIDE
SEMI-CONSCIOUS		ANY	ANY
UNCONSCIOUS		ANY	ANY
PARALYSIS		ANY	L/R
CONVULSIONS		ANY	ANY

* Location of symptoms is used in differential diagnosis and refers to question #52 on the DAN Dive Accident Reporting Form in Appendix A.

Appendix D — Fatality Location Tables

U.S. Fatalities from 1970 to 1991 in Foreign Areas

Country	1970-1979	1980-1989	1990	1991	Country Totals
Anguilla		1			1
Antigua		1			1
Aruba	1				1
Australia	1	2			3
Bahamas	17	19	3	3	42
Barbados		2			2
Bequia			1		1
Bermuda	1	1	1		3
Belize	2	4	1		7
Bonaire				1	1
British Virgin Islands		4			4
Canada	7	6			13
Caribbean Area	27				27
Cayman Islands	3	5	1		9
Central America	1				1
Costa Rica		1			1
Cuba		2			2
Dominica				1	1
Egypt			1		1
Fiji Islands		2			2
French Antilles		2			2
Greece	3	1			4
Honduras		2	1		3
Italy			2		2
Jamaica			2		2
Malaysia		1			1
Martinique		1	1		2
Mediterranean Area	2				2
Mexico	18	28	4	5	55
Micronesia			1		1
Morocco		1			1
Netherlands Antilles		2			2
New Caledonia		1			1
Okinawa	11	3	1	1	16
Palau				1	1
Panama			1		1
Phillipines		2			2
Portugal		1			1
Red Sea		3			3
St. Martin				1	1
St. Vincent/Grenadines		4			4
Saipan		1			1
Thailand		1			1
Saudi Arabia		2			2
Unknown		1			1
Decade Totals	**94**	**107**	**21**	**13**	**235**

U.S. Fatalities from 1970 to 1991 by State

State	1970-1979	1980-1989	1990	1991	State Totals
Alabama	4	2			6
Alaska	9	9			18
Arizona	2	4			6
Arkansas	5	8			13
California	262	155	14	10	441
Colorado	4				4
Connecticut	9	9	1		19
Delaware		3		1	4
Florida	297	231	22	14	564
Georgia	9	11		1	21
Hawaii	63	54	3	3	123
Idaho	2	4			6
Illinois	10	3	1		14
Indiana	6	1		1	8
Iowa	3				3
Kansas	1				1
Kentucky	3	1			4
Louisiana	6	5	1		12
Maine	17	8	3	1	29
Maryland	9	1			10
Massachusetts	39	32	2		73
Michigan	33	12		1	46
Minnesota	5	4		1	10
Mississippi	1	3			4
Missouri	18	3		2	23
Montana		2	1		3
Nebraska	4	5			9
Nevada	4	2		1	7
New Hampshire	4	4			8
New Jersey	25	15	2	4	46
New Mexico	6	4		1	11
New York	38	21	3	2	64
North Carolina	8	12		1	21
Ohio	9	6	1		16
Oklahoma	2	1			3
Oregon	15	11	1	1	28
Pennsylvania	7	7	2	4	20

State	1970-1979	1980-1989	1990	1991	State Totals
Rhode Island	11	19	2		32
South Carolina	7	3			10
South Dakota	1		1		2
Tennesee	5	4		2	11
Texas	32	19	1	2	54
Utah	14	5	1		20
Vermont	2	1			3
Virginia	9	5			14
Washington	96	67	4	1	168
West Virginia	1				1
Wisconsin	20	10	2		32
Wyoming		2			2
Washington DC	1				1
Decade Totals	**1138**	**788**	**68**	**54**	**2048**

U.S. Fatalities from 1970 to 1991 by U.S. Territory

U.S. Territory	1970-1979	1980-1989	1990	1991	Territory Totals
Guam	1				1
Marshall Island	1				1
Puerto Rico	4	5	1		10
Virgin Islands	1	11	1		13
Decade Totals	**7**	**16**	**2**		**25**

Appendix E Fatal Diving Accident Investigation

G. Yancey Mebane M.D., Associate Medical Director, Director EMS Training, Divers Alert Network

The forensic pathologist is usually able to determine a cause of death based on the findings of the autopsy. This cause is usually expressed as a diagnosis of a disease or a pathophysiological event. However, we are interested in the factors which led up to the final event, and this requires investigation of the total incident.

Personal and Past Medical History

A most important part of this investigation is knowledge of the divers' personal characteristics and past medical history. Does the diver meet the standards for physical fitness? No matter what the nature of the accident, being unfit will lessen the chances of survival. The diver should be in a state of physical training consistent with the dive and should have no medical condition that might be aggravated by the effects of pressure or hard physical work.

Pre-existing diseases may predispose to the diving accident. Emotional instability and respiratory infections are particularly important. Medical screening of new divers to detect the presence of physical disqualifications should be required. Adequate initial training followed by further training to match the conditions of the dive is essential. Open ocean, wreck, cold water and other special diving situations require training beyond initial "open water" certification issued by training agencies. A diver who completes an open water certification is not a finished product but is now ready to learn the skills required for special situations such as the open ocean, currents, cold water, limited visibility and others.

The diver certainly should have adequate training for the conditions of the dive. Much criticism is currently directed at some programs which certify after a superficial level of training. Other divers tend to enter specific areas of diving without specialized training. As an example, consider cave diving, wreck diving or ice diving which require special techniques and equipment. Some recreational divers are now experimenting with mixed gas diving, dives past 200 feet and self treatment with oxygen in the water. There have been fatalities reported in 1990 due to amateurish attempts at mixed gas diving and also with dives past 200 feet. The diver must be trained to at least the depth of his dive with the equipment he is to use and for the environmental conditions he will encounter.

Past diving accident history should be taken into consideration. Some disorders experienced by divers in the past are likely to be repeated under similar conditions. These may include:

1. Breath-hold after hyperventilation
2. Panic with hyperventilation
3. Pulmonary barotrauma
4. Nitrogen narcosis
5. Syncope of ascent
6. DCS — especially involving the spinal cord
7. Oxygen toxicity
8. Alcohol and drug history

Environmental Conditions

The weather and environmental conditions at the time of the accident are important. Many fatalities are associated with adverse environmental conditions. The diver may be exposed to increased risk during entry and exit as well as during the dive by any of these factors. A diver swimming against a one knot current is at his limit and probably consuming 2 liters or more of oxygen per minute and ventilating 40 liters of gas per minute per atmosphere pressure. It is practically impossible for a diver to make headway against a 2 knot current.

The temperature of the water will influence hypothermia, decompression sickness and the function of various pieces of diving equipment. Regulators may cease to function when the temperature is at the freezing point. Limited or zero visibility may contribute to the progression of a fatal diving accident following a minor problem.

Entrapment or entanglement is common as a cause of death and includes the diver lost in a cave, wreck or under ice. There have also been open water deaths due to entanglement in lines and kelp. Accidents involving marine animals are very rare, and none were reported in 1990. There was one fatality incident involving sharks.

Dive Profile and History

Essential information includes the location, bottom time and depth of the incident dive as well as recent dives prior to the final dive. The speed of ascent and stops is important information as well as a report of the dive plan. Was there one? Was it followed? Why not?

The degree of physical exertion required by the dive is important to know as the diver unable to meet the physical requirements of the dive is at great risk. All of this is crucial information but often is not available because the divers did not make observations or did not record details.

Diving Equipment

The equipment should be impounded after an accident until a detailed written report can be completed and photographs are taken. The cause of the accident may become apparent with examination of the equipment. The equipment may have been affected by the accident. There may have been loss or displacement of movable items or damage to protective clothing. Gas spaces such as face mask or buoyancy vest may be flooded. Look for vomitus on the mouthpiece or equipment.

The weight belt should be carefully examined and weighed. Determine if it was or could be released. Record the presence or absence of watch, depth gauge, submersible pressure gauge, decompression meter and knife. Record the condition of the buoyancy compensator.

The regulator and cylinder should be examined for defects and the final tank pressure recorded. Samples of the gas within the cylinder should be analyzed for correct partial pressures and the presence of toxic substances.

Appendix F Autopsy Protocol for Victims of Scuba Diving Accidents

Eric P. Kindwall M.D., Associate Professor, Department of Plastic and Reconstructive Surgery, Director of Hyperbaric Medicine, Medical College of Wisconsin.

Jorge Pellegrini M.D., Associate Pathologist, Department of Pathology, St. Luke's Hospital, Milwaukee

The purpose of this protocol is to assist the pathologist in establishing immediate cause of sudden death in the water. In a pressure related diving accident, the traumatic agent is a simple gas which, although causing death, is evanescent and may go undetected using the standard autopsy routine. Cerebral air embolism has often been inadvertently signed out as simple drowning. It is important to remember that cerebral air embolism can occur in water depths as little as 1.12 meters (4 feet) and can produce fatal results within less than one minute of surfacing. Post mortem bubbles often confuse the issue. This protocol should be filed for future use when performing an autopsy on a scuba diver.

Introduction

Since the advent of civilian sport scuba diving (Self-Contained Underwater Breathing Apparatus) as a major recreational pastime, diving accidents have inevitably increased and of necessity, pathologists with little previous knowledge of diving, are called upon to perform autopsies when accidents cause fatality. This poses difficult problems as there have been no protocols widely disseminated for use by pathologists in carrying out these highly specialized postmortem examinations. The purpose of this protocol is to assist the pathologist in establishing the immediate cause of sudden death in the water, and little emphasis is given to long term or chronic changes associated with decompression accidents.

In a pressure related diving accident, the traumatic agent is a simple gas or mixture of gases which although causing death, is evanescent and very well may go undetected when the standard autopsy routine is followed. As a result, many cases of cerebral air embolism have been inadvertently signed out as simple drowning. It is important to remember that cerebral air embolism can occur in water depths as little as 1.12 meters (4 feet) and may produce fatal results within a minute or two of surfacing.

Sometimes bubbles are found in blood vessels at autopsy tempting the pathologist to diagnose "bends" or decompression sickness as the cause of death when in reality the bubbles were formed postmortem. With a good understanding of the mechanisms involved and knowledge of a proper autopsy technique, much more accurate assessment of the cause of death can be made.

This protocol should be filed for future use when performing an autopsy on anyone who has died while wearing a scuba apparatus or for that matter, any type of compressed air diving apparatus. This would even include a bucket worn over the head under water supplied with air from a garden hose and tire pump.

Diagnoses to Consider

Aside from obvious trauma such as propeller injury or a natural illness such as stroke or myocardial infarction, the Scuba diver is most likely to suffer:

1. Cerebral air embolism with or without mediastinal emphysema and pneumothorax.
2. Drowning.
3. Decompression sickness.
4. Bites or stings from venomous marine animals.

The pathologic findings in drowning will not be considered here as they are covered in standard reference works.

Cerebral Air Embolism

The mechanism of arterial gas embolism hinges on the fact that while using a compressed air scuba apparatus the air pressure in the lungs at depth is in equilibrium at all times with the pressure of the water surrounding the diver so long as he breathes normally. Thus it is greater than atmospheric. If the diver, through carelessness or in a panic, ascends only a few feet holding his breath, the air in the lungs expands as water pressure decreases, and forces its way through alveolar walls. Dog experiments have shown that a trans-pulmonic pressure of 80mm Hg is enough to rupture the alveoli.[3] This 80mm pressure differential between the intra-tracheal pressure and the intra-pleural pressure corresponds to a change in sea water pressure of a little more than one meter (four feet). After passing out of the alveoli, the air may migrate medially producing pneumomediastinum and in some cases pneumopericardium or it may rupture a bleb on the pleural surface causing pneumothorax, though this latter tends to be rare. The worst situation which can commonly occur is that air enters the pulmonary capillaries and is carried via the pulmonary veins to the left heart. From there it is pumped directly into the brain. Scuba tanks are filled with compressed air, never oxygen which becomes too toxic at depth, so resultant arterial bubble contain mostly nitrogen. Air embolism will produce air bubbles in the meningeal and cerebral arteries and possibly in the coronaries. However, because the diver invariably embolizes in a head up position while vertically ascending through the water, mesenteric, spinal cord and the vertebral arteries and bones are seldom involved.

It must be emphasized that this event cannot take place if the swimmer is simply breath-hold diving. The victim must have been breathing air at greater than normal pressure under water using some kind of breathing apparatus or appliance.

Because sudden death occurring in the family swimming pool while using scuba gear is not easily attributable to the scuba itself in the minds of most people, the possibility of gas embolism is often overlooked. Again, experiments have demonstrated that as little as 0.4 ml of blood-air foam delivered to the right spot in the brain stem may produce death. In the clinical situation, when death does not immediately ensue, the patient often enters the emergency room with the signs and the symptoms of having suffered a cerebro-vascular accident. This can mistakenly be attributed to ruptured berry aneurysm or some other vascular catastrophe. As a rule of thumb, anyone dying while using scuba apparatus should be considered to have suffered an air embolism as the initiating event until proved otherwise.

Pathologic Findings in Air Embolism

1. Intra-arterial and intra-arteriolar air bubbles in the brain and meningeal vessels, with possible petechial hemorrhages in the white and gray matter.
2. Ruptured alveoli or acute pulmonary emphysema on microscopic examination. This is often hard to document because of sectioning artifact causing tears of alveolar walls.
3. Grossly hemorrhagic lungs.
4. Possible voids due to air bubbles in the capillaries surrounding the alveoli.
5. Ring and ball hemorrhages in the brain.
6. Signs of acute right heart failure. The heart, if it contains air, may float when surrounded by water.
7. Passive congestion of the kidneys.
8. Liebermeister's sign (white mottling of the dorsum of the tongue).
9. Air bubbles in the retinal and coronary arteries.
10. Mediastinal emphysema.
11. Pneumo-pericardium.
12. Subcutaneous emphysema above the clavicles to the angle of the jaw (should be palpable).
13. Pneumothorax.

It would be unusual to find changes such as softening of neural tissue, changes in Ammon's horn and gliosis because air embolism usually causes nearly instant death. If the patient survives the immediate insult, he usually does not die although he may remain severely crippled as a late result of air embolism blocking the vascular supply with its secondary consequences.

Decompression Sickness or Bends

When a diver breathes air under increased pressure, nitrogen from the air goes into physical solution in his blood and tissues. This causes him no difficulty while on the bottom, (aside from an increasing narcotizing effect as he exceeds 30 meters (100 feet) in depth. However, if he has dived deeper than 10 meters (33 feet) and has remained for a long enough time to absorb significant amounts of nitrogen, gas bubbles are formed in his tissues and capillaries as nitrogen comes out of solution if he returns rapidly to the surface. Nitrogen bubbles of themselves can block circulation, tear neural tissue and also initiate complex biochemical changes causing platelet aggregation, agglutination of formed elements of the blood, sludging, stasis infarction and shock. Symptoms range from pain to paresthesias, paralysis (usually the middle third of the spinal cord), asphyxia (as pulmonary capillaries are blocked), shock and death. It is important to remember that decompression sickness (especially producing fatality) *is unlikely to occur unless* the diver has been at a depth *in excess of 10 meters (33 feet).* The time required to absorb damaging amounts of nitrogen varies inversely with depth. For example, one can spend up to 200 minutes at 12 meters (40 feet) and come directly to the surface without pausing on the way for decompression stops. However, this time is reduced to 25 minutes at 30 meters (100 feet) and only 5 minutes at 50 meters (165 feet). Bottom time is reckoned as the time between leaving the surface and leaving the bottom. Normal ascent rate is never more than 18 meters (60 feet) per minute.[5]

Assuming the diver has made a safe dive, whether requiring decompression stops on ascent or not, when he arrives on the surface he will still have more than normal amounts of nitrogen in his tissues. This will slowly be lost over the next 12 to 24 hours. Should he make another dive within that time, he must take into account the residual nitrogen present in his body at the beginning of the second dive. This will be additive to the nitrogen absorbed on the second dive, and he must shorten his

second dive or lengthen his decompression time in accordance with the length of the surface interval between the dives.

There are special U.S. Navy repetitive dive decompression tables for use in calculating length of stay or decompression requirements for repetitive dives within 12 hours.[5] Repetitive diving is a frequent cause of decompression sickness in sport divers either because they miscalculate or fail to observe any decompression rules.

All of the above has relevance to the pathologist as it demonstrates that greater than normal amounts of nitrogen are present in the diver's body even during safe dives. If the diver should die from any cause either on the bottom or within 12 to 24 hours of the dive, nitrogen will cease being carried from the tissues and eliminated through the lungs. Therefore, it will gradually revert to gas phase *in situ* producing *postmortem* bubbles which, in such cases, will have no bearing on the cause of death. Postmortem nitrogen bubble formation, however, will be minimal or absent if the victim has died during or following short exposures to depths of less than 10 meters.

The obvious pathological findings in someone dying acutely of decompression sickness can only appear as bubbles consisting mostly of nitrogen in any tissue of the body. These bubbles usually originate on the *venous* side but when blood pressure disappears, bubbles will merge even on the arterial side. During life, the blood pressure in the arteries tends to prevent bubble formation except in cases of almost explosive decompression. The lesser pressure present in the veins permits the earlier appearance of bubbles and indeed, during normal, safe and asymptomatic decompression so-called "silent" bubbles can be detected frequently with Doppler sonar over the vena cava. In decompression sickness as already discussed, the bubble will usually represent postmortem bubble formation and therefore, cannot reliably be used to certify the cause of death to be due to too rapid decompression. This is always true if the patient died while under pressure in a recompression chamber or died after spending some time at depth with subsequent recovery of the body from the bottom. The clinical history must invariably be relied upon to establish cause of death in cases of decompression sickness. Following acute death from massive decompression sickness, such as explosive decompression, there will not have been time for tissue reaction such as gliosis, etc., to take place. The pathologist's task in such cases will be to differentiate between air embolism and decompression sickness as the immediate cause of death. In other cases where death is not immediate, the history and clinical course will amply serve to establish the cause of death. Prominent will be lesions in the white matter of the middle third of the spinal cord with evidence of stasis infarction. The brain is usually spared except in cases of aviation decompression sickness.[2]

Venomous Stings or Bites from Marine Animals

1. A bite or sting on any part of the body.
2. Unexplained edema on any part of the body.
3. Pathologic change consistent with anaphylaxis or other strong allergic reaction.

In marine animal stings the history is often suggestive, but the body should be examined very carefully to detect lesions that might have gone unsuspected. Occasionally, a relatively minor bite or sting may precipitate panic or incapacitation which subsequently leads to death by embolism or drowning. A point to keep in mind, however, is that some marine animal bites may take place after death. In such cases, tissue reaction will not occur as compared to bites occurring ante-mortem.

It is important to remember that in *all* pressure related diving accidents, the presence of bubbles formed *postmortem* may tend to cloud and confuse the pathologic diagnosis. The length of time which passes between death and the autopsy as well as the amount of body tissue decomposition which takes place requires that the pathologist exercise good judgment in coming to his final conclusions as well as careful performance of the autopsy which includes an analysis of the gases found.

Preliminary Preparation for the Autopsy

1. Obtain a history from the referring physician, rescue squad and/or the victim's diving companions. This will alert the pathologist as to what he must include or may omit in his consideration of the autopsy findings. Determine the dive profile(s), whether or not the victim dropped his weight belt, inflated his vest, etc. If possible, the diving rig or scuba apparatus should be recovered and retained for future examination. Such examination would include presence of blood or vomit in the regulator or hoses, the amount of air left in the tank(s) and an analysis of the air for contaminants such as carbon monoxide or oil; whether or not the regulator functions properly, its breathing resistance, etc., the status and operability of the lifevest, depth gauge, reserve air gauge, position of the J valve and the status and function of the buoyancy compensator if one was used. An expert familiar with scuba equipment should assist with such examination.

2. X-ray the head, neck, thorax and abdomen of the victim for soft tissue detail (free air) as well as bone injury.

3. Prepare a number of tight fitting, well greased 10cc syringes equipped with 3-way stop cocks and long spinal needles.

4. Obtain a 50cc graduate and fill a deep sink in the autopsy room with water.

5. Provide a hose to the autopsy table so that a gentle stream of water may be directed into the area being examined. Notify the laboratory that you wish to have gas samples analyzed for oxygen and carbon dioxide. (Nitrogen content of the gases may be obtained by subtraction.)

The Autopsy

Inspect the body carefully for signs of trauma or other unusual lesions. Do not forget to look at the back. Palpate the area above the clavicles and below the angles of the jaw for signs of subcutaneous emphysema.

Make an incision through the full thickness of the skin down the midline of the sternum beginning at the second intercostal space. Continue the incision down to the origin of the xyphoid process.[4] Secondly, make two transverse incisions at the ends of the initial vertical incision carrying them laterad a couple of centimeters. Apply towel clips to the skin edges and using blunt and sharp dissection, undermine the skin laterad. Two assistants then "tent up" the skin, and the resultant compartment created above the chest wall fills with water. The 50cc graduate is then completely filled with water in the deep sink, inverted with the palm or a cork occluding the open end, is brought over to the victim and the occluded end immersed in the compartment of water over the sternum. An 18 gauge needle is then inserted into the pleural space at the level of the second intercostal space. The open end of the graduate should be positioned directly above the needle so that

any gas issuing from the pleural space is trapped in the graduate. The amount of gas recovered is recorded. Then, with the bottom of the graduate again occluded, it is brought over to the deep sink, and a 10cc syringe with a long spinal needle is inserted in the graduate so that the gas may be withdrawn for analysis. Before the syringe is removed from the water, the stop cock is closed. Should it be impossible to reach the gas pocket at the top of the graduate, the gas may be transferred to a 50cc beaker, previously filled completely with water in the deep sink by upending the graduate underneath the inverted beaker. Gas may then be withdrawn from the beaker. If the water is warm and this maneuver is carried out rapidly, there will be little absorption of CO_2. Repeat the process on the other side.

The sternum is then transected at the level of the second intercostal space, and the ribs are divided just medial to the costochondral junction. The section of ribs and sternum is removed.

Observe as one goes along whether or not bubbles issue from the cut ends of any vessels. This applies throughout the autopsy. The vessels should be identified if possible as to whether they are arteries or veins. The water in the compartment formed by this skin "tent" will probably become discolored by blood making it opaque. If discrete blood leakage points can be identified, they may be cross-clamped. As the field becomes opaque, fresh water is introduced with the hose to retain visibility. The pericardial sac is opened under water after is has been determined whether or not pneumopericardium is present. A needle is then inserted into the right and left ventricles in turn again in a flooded field with the inverted graduate held over the needle so that the escaping gas may be trapped, the amount recorded and the gas analyzed.

As the mediastinal structures are dissected, note carefully the presence or absence of gas in each discrete compartment as it is opened, bubbles being apparent as they rise through the water. Dissection should be meticulous as if a major vessel is entered early, the field will become too opaque. The hose can be used to flush the blood out to produce a clear field. When the mediastinum, heart and major vessels have been examined under water for the presence of air, the water may be evacuated from the thoracic cavity, and the autopsy proceeds in the conventional manner. Carefully examine the lungs for signs of bullae or emphysematous blebs or hemorrhage (gross or petechial). Carefully check individual lobes or broncho-pulmonary segments for evidence of bronchial obstruction which might have given rise to blockage of the affected area during decompression such as mucous plugs, broncholiths, foreign bodies, etc. Obtain blood, urine and bile samples for analysis for alcohol or other drugs.

Be sure to probe the heart for evidence of inter-atrial or inter-ventricular septal defect. As the autopsy proceeds, note if there are signs of venous congestion compatible with right sided heat failure. In a case of air embolism where autopsy takes place soon after death, and *before* postmortem bubble formation has taken place, the right ventricle should not contain gas unless there is an inter-atrial septal defect. Gas in the heart, present only in the left ventricle is pathognomonic of arterial air embolism which in the scuba diver becomes cerebral air embolism. If the victim has made a short shallow dive and has suffered air embolism, the left ventricle should contain gas with an oxygen content approaching 16 percent. If bubbles are found after a dive of a long duration or there has been considerable time lag between death and autopsy, the gas bubbles in the heart will be predominantly nitrogen or CO_2, respectively or both.

Head

Ideally, it would be best if the entire autopsy could be carried out under water, but this is not practical as when major vessels are opened, the water becomes impossibly opaque.

Before opening the head, tie all of the vessels in the neck so as to preclude the entrance of air into the cerebral or meningeal vessels from below.

After careful examination of the head and neck, the scalp is reflected and the calvarium removed with a saw as is customary. As the calvarium is removed, bubbles may appear as artifacts in the superficial veins or venous sinuses. These can safely be disregarded.[1] The arteries of the meninges should be examined for the presence of gas and then after exposing the brain, gas bubbles should be looked for in the surface vessels. The frontal lobes are reflected back and after the optic nerves have been cut, carefully examine the Circle of Willis for bubbles. Air appearing here is particularly significant. The middle cerebral arteries are also examined in situ by carefully spreading the insula. Photograph any bubbles found.[1] The brain is then removed and fixed.

Interpreting Results

The presence or absence of gas in any organ following a scuba diving death can never be conclusive evidence of decompression sickness. With the exception of the case where air is found only in the left ventricle (but not in the right) and in cerebral arteries (but not veins), air embolism cannot be diagnosed simply by the presence of bubbles. However, under certain circumstances gas analysis of the intracardiac air can be revealing. If there is a difference in the oxygen content of gases obtained from the right and left sides of the heart, with more oxygen being present on the left, one can only come to the conclusion that air was introduced traumatically into the arterial circulation. Postmortem bubbles contain little, if any, oxygen, and the same is true for decompression sickness bubbles. When taken in context with the circumstances of the dive and other information which may be provided to the pathologist, gas analysis can help to establish a diagnosis.

In summary, if the basic mechanisms of air embolism, decompression sickness, mediastinal emphysema and pneumothorax stemming from scuba diving are understood by the pathologist, the results of the careful autopsy may often be able to distinguish between a pressure related mechanism of death and simple drowning. The same is true for the potentially fatal consequences of venomous animal sting.

References

1. Edmonds, C., Lowry, C., and Pennefather, J. (1976). *Diving and Subaquatic Medicine*, Diving Medical Centre, Mosman, N.S.W. Australia.
2. Minckler, J. M.D., Ph.D. (1971). *Pathology of the Nervous System,* Vol. 1, McGraw-Hill Book Company, New York.
3. Schaefer K.E., McNulty, W.P. Jr., Carey, C.R., and Liebow, A.A. (1958). Mechanisms and development of interstitial emphysema and air embolism on decompression from depth, *J. Appl. Physiol.* 13:15.
4. Spitz, W.U., and Fisher, R.S. (1973). *Medicolegal Investigation of Death,* Charles C. Thomas, Springfield, Illinois.
5. *U.S. Navy Diving Manual* (1973). Navships 0994-001-9010, Navy Dept., Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

Appendix G Occupational Diving Fatalities

John J. McAniff, Director, National Underwater Accident Data Center, University of Rhode Island

The following is an analysis of seven occupational underwater diving fatalities for the calendar year 1991. The categories which appear at the end of this report have been established in agreement with the National Oceanic and Atmospheric Administration (NOAA), the Occupational Safety and Health Administration (OSHA), and the U.S. Coast Guard (USCG).

In the single Category C-I fatality, a 37-year-old male had been using a burning torch in the removal of a well stub at a depth of 257 feet in the Gulf of Mexico when there was a sudden free-flow. It was concluded that a burning explosion may have occurred causing the man's face plate to come loose. Extensive investigation of this case resulted in a specialized torque test for the face plate screws.

The first of two Category C-II fatalities took place at a Texas public utilities plant in March. Two professional scuba divers had been taking turns entering the lake's intake system to clean away rubble. The victim, a 44-year-old male, was found two hours after his dive commenced with no air left in the tanks. Each diver had worked with scuba gear, no communications and no safety lines.

A 31-year-old male who was reported to be a diver, firefighter and medical technician, but not a commercial diver, was asked to check a gate which would not close properly at a hydroelectric power station. Almost immediately he became trapped by the suction of the partially open gate. Attempts to pull him free using his safety line were unsuccessful. The victim was recovered from about 15 feet of water after some of the plant's systems were shut down. The diver had then been in 31°F water for about 100 minutes. The autopsy report indicated death by asphyxiation due to drowning and hypothermia.

In 1991, three cases were reported in the Category C-IV (marine harvesting). All three fatalities occurred while the victims were harvesting sea urchins.

In the first incident, a 44-year-old male was diving in 50 feet of water when he suffered an air embolism. He apparently surfaced very rapidly after either ditching or accidentally losing his weight belt. He never regained consciousness.

Two deaths resulted from the same incident. The two victims were using a surface-supplied-air hookah system driven by a gasoline engine. The system was operating from the bilge area of the boat, below deck with inadequate ventilation. The men, aged 29 and 34, succumbed to carbon monoxide poisoning.

A 33-year-old male died while engaged in the capture of sea life for aquariums. This death has been listed in Category C-VII, a catch all for deaths that do not fit into the other occupational sectors.

This victim had been diving commercially for only two weeks at the time of his demise. He was reported to be using a surface-supplied-air hookah system but had little or no training. The tender suddenly found no one at the end of the air line. The victim was located on the bottom with the regulator out of his mouth and his mask off, but with his 120-pound weight belt still in place. He was rushed in for chamber treatment but never regained consciousness. The cause of death was

attributed to drowning despite the large amounts of air found in the right heart and elsewhere. Air embolism as a factor could not be ruled out.

Preliminary Information on 1992 Occupational Fatalities

As this report goes to press we have had a total of eight occupational diving fatalities reported for 1992.

A double C-II ice fatality occurred after two divers were hired to located and cap a pipe. The individuals were recreational divers and did not use guidelines, a safety diver, or a topside observer.

A 27-year-old male was reported dead after an accident. This victim was excavating with an air hose when his helmet was allegedly blown off. (C-I).

A nuclear power station was the site of the death of a 37-year-old male who was engaged in cleaning operations and apparently received less air than he demanded from a surface-supplied-air system. Carbon dioxide build-up may have also played a part in this fatality. (C-II).

A 28-year-old male became lost under ice in January while attempting repairs on a small boat at the end of the dock. This man was operating with scuba gear but without a safety line or tender. (C-III).

A 23-year-old male died in 15 feet of water while harvesting sea urchins and using scuba gear. (C-IV).

A 47-year-old male died in 12 feet of water in a golf course pond while attempting to recover lost golf balls for resale. When recovered, he was noted to be using an 80lb weight belt and had more than 70 pounds of golf balls in a sack tied to his waist. (C-VII).

A 35-year-old state trooper lost his life in swift running water at a gorge while attempting to recover the body of another drowning victim. The officer lost his mask and regulator and became wedged in underwater boulders. The river had to be dammed to ease the flow and allow recovery of the body. (O-H).

Occupational Fatality Table

Categories	1970-1974	1975-1979	1980-1984	1985-1989	1990	1991
Commercial I	6	12	5	1	1	1
Commercial II	17	23	20	21	3	2
Commercial III	0	3	4	0	0	0
Commercial IV	14	21	18	22	6	3
Commercial V	0	0	1	0	0	0
Commercial VI	2	0	0	0	0	0
Commercial VII	5	3	5	8	0	1
Occupational F	3	0	2	0	0	0
Occupational G	2	6	6	1	3	0
Occupational H	3	3	7	8	0	0
Occupational I	0	0	0	0	0	0
Occupational J	2	0	0	1	1	0
Occupational K	1	2	3	2	0	0
TOTALS	**55**	**73**	**71**	**64**	**14**	**7**

Occupational Fatality Category Definitions

Commercial I (C-I)
Offshore construction and salvage diving, plus oil and gas-related
Commercial II (C-II)
Harbor and inland diving, such as construction, shallow pipe inspection, salvage and repair.
Commercial III (C-III)
Ship-related diving, such as construction, repair and hull cleaning.
Commercial IV (C-IV)
All types of commercial fisheries: abalone, sea urchin, seaweed harvesting, black coral diving, etc.
Commercial V (C-V)
Scientific diving for paid consulting purposes.
Commercial VI (C-VI)
Diving while in training for professional diving.
Commercial VII (C-VII)
Other types of commercial diving not specifically set forth in the above categories, such as underwater photography, private research, commercial treasure diving, archeological diving.

The categories which are not strictly commercial but are occupational in nature are listed as follows:
Academic (F)
Scientific research by persons associated with an academic institution.
Government, military (G)
On-duty divers in the U.S. Navy, U.S. Army, U.S. Coast Guard, etc.
Government, civil (H)
Local, state and federal employees, such as police and fire department search and rescue units, etc.
Instructor, commercial (I)
Those actively engaged in teaching commercial and professional diving.
Instructor, recreational (J)
Certified instructors actively engaged in teaching sport and recreational diving.
Scientific diving (K)
Individuals who meet the OSHA definition of scientific diving or are clearly a part of a scientific diving community.

Appendix H ICD-9-CM Codes for Dive Related Incidents

36.10	Coronary artery bypass graft
245.1	Chronic thyroiditis
250.0	Diabetes mellitus
250.4	Diabetes mellitus w/ glomerulosclerosis
278.0	Obesity, exogenous
293.0	(Nitrogen narcosis)
293.0	Acute confusional state
303.0	Ethanol acute intoxication
305.0	Alcohol abuse (acute)
305.1	Tobacco abuse
308.0	Panic state
336.1	Intraparenchymal hemorrhage of spinal cord
348.1	Anoxic brain damage
348.5	Cerebral edema
401.9	Hypertension
402.0	Hypertensive vascular disease (HVD)
404.0	HVD w/ renal involvement
410.9	Acute myocardial infarction
414.0	Coronary atherosclerosis
414.9	Coronary artery disease
425.4	Hypertrophic cardiomyopathy
427.9	Cardiac dysrhythmia (unspecified)
427.41	Ventricular fibrillation
428.0	Congestive heart failure
428.1	Left heart failure (pulmonary edema)
429.2	Arteriosclerotic cardiovascular disease (ASCVD)
429.3	Ventricular hypertrophy (cardiomegaly)
436	Cerebrovascular accident (CVA)
490	Chronic obstructive pulmonary disease
492.0	Emphysematous blebs
493.9	Asthma (unspecified)
496	COPD
508.9	Pulmonary edema due to external agent
512.0	Spontaneous pneumothorax
518.5	Acute respiratory distress syndrome (ARDS)
571.2	Cirrhosis of liver (alcoholic)
780.0	Coma
780.3	Seizure disorder
786.3	Pulmonary hemorrhage
798.1	Instantaneous death, cause not discovered
798.2	Death within 24 hours, cause not discovered

798.9	Body found after 24 hours, cause not discovered (i.e., mutilated, skeletonized, etc.)
799.9	Death, unspecified cause (body not found)
81.59	Bilateral hip prosthesis
860.0	Pneumothorax, tension, traumatic
958.0	Air embolism
958.7	Subcutaneous emphysema
980.0	Ethanol, toxic effect
986	Carbon monoxide
993.0	Barotrauma, otitic
993.1	Barotrauma, sinus
993.3	Decompression sickness
993	Barotrauma
994.1	Drowning and non-fatal submersion
E830	Watercraft accident (overturn)
E838.5	Struck by boat
E902.2	Rapid ascent
E906.3	Shark bites
E910.1	Recreational activity with diving equipment
E910.3	Diving for purposes other than recreation with diving equipment (i.e., marine salvage, rescue, construction, etc.)
E913.2	Insufficient air
E918	Caught, entangled, entrapment (specify)
E918.1*	Shipwreck
E918.2*	Cave, cavern, marine or freshwater
E918.3*	Ice
E918.4*	Kelp (or other underwater vegetation)
E918.5*	Rope, line, cable, diving equipment
E918.9*	Other entrapment
E934.4	Benzodiazepine
E935.2	Codeine
E935.8	Propoxyphene
E937.0	Butalbital
E939.0	Fluoxetine (Prozac)
E939.0	Nortriptyline
E980.3	Cannabinoids
E980.3	Methamphetamine

* DAN adaptation of code

Appendix I Diving Definitions

Buoyancy Control — The ability to maintain neutral buoyancy. Common causes are a current pushing a diver either up or down, being either over or underweighted, overinflation of BCD, or lack of the actual skill.

Current — Refers to a strong or moderate current being present during the day of interest.

Day of Interest — Usually considered to be the day of the accident.

Decompression Diving — Diving exposure that requires staged in-water stops before continuing to the surface.

Exertion — The diver may exercise more than normal on a dive on the day of interest. The main causes of exertion during a dive are current or extra equipment (for photography or specialty diving).

Fatigue — At the time the diver first entered the water on the day of interest, the diver may have complained of being tired, experiencing a lack of sleep, or a generalized fatigue.

≥ 80fsw — One dive in the diver's profile on the day of interest is at 80 feet of sea water or deeper.

< 2 year Experience — The diver had been diving for less than 24 months on the day of interest.

Multi Day — More than one day of diving was done in this particular dive series. Multi day and single day are mutually exclusive.

Multilevel Dive — The diver descends to one depth, staying at that depth for a while then either ascending or descending to a new depth for a while. Many different levels can be visited in one dive before finally ascending (for example, a diver descends to 60 feet and stays for 10 minutes then descends to 80 feet and stays for 5 minutes, ascends to 50 feet for 10 minutes and then to 20 feet for 5 minutes before surfacing).

No Decompression — A dive which is within the recreational diving limits, not requiring a staged stop to allow the amount of nitrogen in body tissues to decrease before continuing to the surface. This can be with either tables or computers.

Rapid Ascent — The recommended ascent rate is 60 feet per minute. A rapid ascent occurs when a diver ascends faster than recommended. Rapid ascents are often uncontrolled and can be caused by overinflation, being underweighted or panic.

Repeat Dive — More than one dive was done on the day of interest. Single dive and repeat dive are mutually exclusive.

Single Day — Only one day of diving was done in this particular dive series. Single day does not denote the number of dives, rather a single day of diving (for example, four dives could be done in a single day, or one dive could be done in a single day).

Single Dive — Only one dive was done on the day of interest.

Square Dive — The diver descends to maximum depth staying at that depth until ascending to the surface (for example, a diver descends to 60 feet and stays at 60 feet for 30 minutes before ascending). Square and multilevel dives are mutually exclusive.

Within Tables — A dive which is within the allowable limits of the dive table used by the diver.

Notes