+ Divers Alert Network +

Report on Decompression Illness and Diving Fatalities

DAN's Annual Review of Recreational Scuba Diving Injuries and Deaths Based on 1997 Data

1999 Edition

US $25

Report on Decompression Illness and Diving Fatalities

1999 Edition

The annual review of scuba diving injuries and deaths based on 1997 data

by

DAN

Divers Alert Network

Divers Alert Network

This 1999 edition covers injuries and fatalities that occurred from Jan. 1-Dec. 31, 1997.

Divers Alert Network's *Report on Decompression Illness and Diving Fatalities* presents self-reported, retrospective data from hyperbaric treatment facilities. This edition covers reports on decompression illness and diving-related fatalities that occurred in the calendar year 1997: Jan. 1 - Dec. 31, 1997. It is referred to throughout as "the report," or as the 1999 edition of the report.

In 1997, 972 cases of decompression illness (DCI) were reported to DAN through telephone contact with hyperbaric treatment facilities. DAN received *Diving Accident Reporting Forms (DARFs)** on 634 of these cases. Of these 634 reports, 452 DCI cases met the criteria for inclusion in the DAN 1997 database (see Page 19). Trends in the injury database are reported on an 11-year period, from 1987 through 1997. The report also reviews 82 recreational scuba fatalities that occurred involving U.S. and Canadian citizens worldwide.

DAN's reporting forms on injuries, fatalities and dive incidents, which have previously appeared as appendices in past editions of this report, have been removed. Copies of these reporting forms are available through DAN's Research Department at 800-446-2671, +1-919-684-2948 or on DAN's website at www.diversalertnetwork.org.

The *Dive Incident Form*, used to document events that lead to "near-misses" but do not result in a decompression illness or dive fatality, are also on DAN's Worldwide Web pages. Incident reporting is important to DAN's data collection: although no harm has come to the diver, this collection of incident data could help provide answers to dive safety questions.

As with most DAN programs, the majority of the funding for this report is derived from annual DAN membership dues. DAN also wishes to recognize the many DAN Sponsor dive clubs, stores, instructors, corporations and friends of DAN who support Divers Alert Network and dive safety.

Cover photo by DAN member Dave Haas
Cover design by Phillip Daquila

* *Note: In 1998 DAN revised the* Diving Accident Reporting Form (DARF) *into a more standardized reporting format known as the* Diving Injury Report Form, *or* DIRF. *The DIRF has been developed to describe symptoms more accurately, enhance diagnosis, assist in classification and reduce uncertainty about the diagnosis of DCI.*

Acknowledgments

Data for the *1999 Report on Decompression Illness and Diving Fatalities* have been collected and assembled by DAN employees and associated staff. These contributions range from injury follow-up calls, data entry, editing, proofreading and compiling the final report. DAN wishes to recognize the following people for their important contributions:

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DAN Senior Medical Staff

DAN Volunteer Physicians

Find DAN's
- ***Dive Incident Form***

and the
- ***Diving Injury Report Form***

on DAN's Worldwide Web pages or through DAN's Medical Research Department.

DAN Regions and Regional Coordinators for Hyperbaric Treatment

Divers Alert Network uses a network of 270 hyperbaric chambers in the United States and around the world to report decompression illness (DCI) injuries. The DAN network is now divided into eight regions, each overseen by a Regional Coordinator.

International Headquarters and Southeast Region — *Alabama, Georgia, North Carolina, South Carolina and Tennessee*

Peter Bennett Ph.D., D.Sc. and Richard Moon M.D.
F.G. Hall Hyperbaric Center, Box 3823, Duke University Medical Center, Durham, NC 27710

Southwest Region — *Arizona, California, Nevada and Utah*

Hugh Greer M.D.
Santa Barbara Medical Foundation Clinic, Department of Preventive/Occupational Medicine, Box 1200, Santa Barbara, CA 93102

Northeast Region — *Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Virginia and West Virginia*

Roy Myers M.D. and Cynthia Cotto-Cumba M.D.
Department of Hyperbaric Medicine, Maryland Institute for Emergency Medical Services Systems, University of Maryland, 22 S. Greene Street, Baltimore, MD 21201

Gulf Region — *Arkansas, Colorado, Kansas, Louisiana, Mississippi, Missouri, New Mexico, Oklahoma and Texas*

Keith Van Meter M.D. and Randy Springer, CHT
Jo Ellen Smith Medical Center, 4400 General Meyer Avenue, New Orleans, LA 70131

Midwest Region — *Illinois, Indiana, Iowa, Kentucky, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin and Wyoming*

Jeffrey Niezgoda M.D. and Mr. Stephen Fabus
Department of Hyperbaric Medicine, St. Luke's Medical Center, 2900 W. Oklahoma Avenue, Milwaukee, WI 53215

Northwest Region — *Alaska, Idaho, Montana, Oregon and Washington*

Neil Hampson M.D. and Richard Dunford M.S.
Hyperbaric Department, Virginia Mason Research Center, 952 Seneca Street, Seattle, WA 98111

Pacific Region — *Guam, Hawaii and U.S. Territories*

Robert Overlock M.D. and Mr. Frank Farm
Hyperbaric Treatment Center, University of Hawaii, John A. Burns School of Medicine, 347 N. Kuakini Street, Honolulu, HI 96813

Florida and Caribbean Region — *Florida and Caribbean Basin*

Harry Heinitsh, M.D. and Mr. Marc R. Kaiser
Diving Medical Center at Mercy Hospital, 3663 South Miami Avenue, Miami, FL 33133

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DAN – *Your* Dive Safety Association

DAN was founded in 1980 to provide an emergency hotline to serve injured sport divers and the medical personnel who care for them.

For scuba divers worldwide, DAN means safety, health and peace of mind. DAN is a 501(c)(3) non-profit dive safety organization affiliated with Duke University Medical Center in Durham, N.C., and is supported by the largest membership association of divers in the world. DAN members comprise the largest association of recreational divers in the world.

DAN was founded in 1980 to provide an emergency hotline to serve injured recreational divers and the medical personnel who care for them. Originally funded by government grants, today Divers Alert Network relies on membership, dive industry sponsors, product sales and fund-raising to provide the high level of service the dive community has become accustomed to receiving.

DAN America's Services to the Recreational Diving Community

DAN is best known for its 24-Hour Diving Emergency Hotline, the Dive Safety and Medical Information Line and its dive-related medical research programs. However, DAN America and its affiliates in Europe, Japan, Southeast Asia and Southern Africa also serve the recreational scuba community with dive first aid training programs, dive emergency oxygen equipment, affordable dive accident insurance, and books and videos on scuba safety and health.

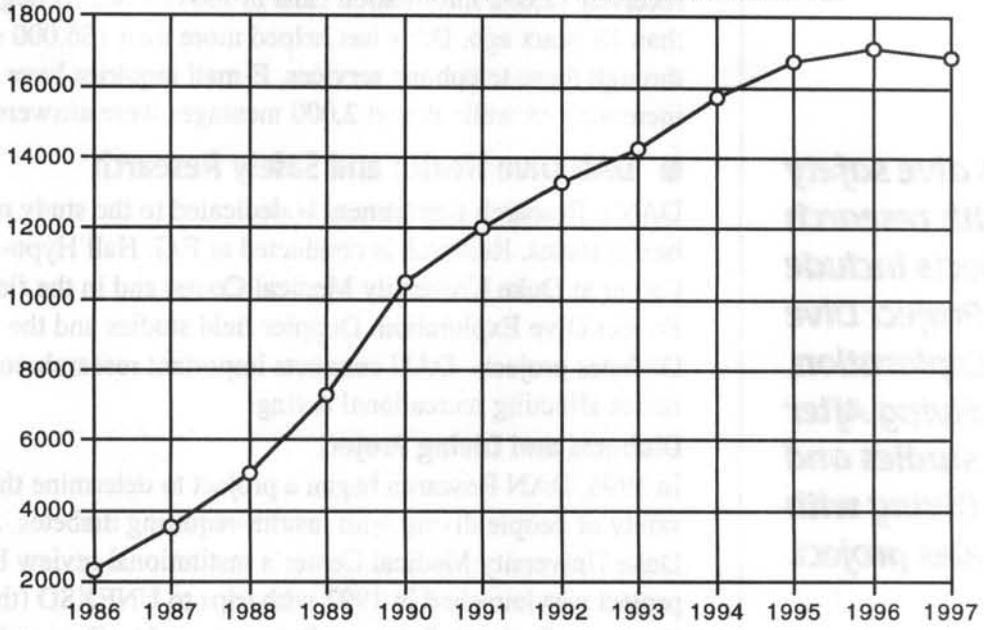
DAN's Mission

✦ DAN's historical and primary function is to provide emergency medical advice and assistance for underwater diving injuries, to work to prevent injuries and to promote diving safety.

✦ DAN promotes and supports underwater diving research and education, particularly as it relates to the improvement of diving safety, medical treatment and first aid.

✦ DAN strives to provide the most accurate, up-to-date and unbiased information on issues of common concern to the diving public, primarily, but not exclusively, for diving safety.

DAN Emergency and Information Services Combined Call & E-Mail Volume Numbers



■ DAN Diving Emergency Hotline – (919) 684-8111 or collect at (919) 684-4DAN (4326)

The 24-Hour Diving Emergency Hotline is DAN's premier service. The medical information specialists and DAN physicians offer emergency consultation and referral services to injured divers worldwide. In 1997 DAN answered more than 2,200 calls for emergency assistance from its members and divers.

In 1997, DAN took more than 2,200 calls for emergency assistance from members and divers.

■ DAN Medical Information Line – (919) 684-2948 or 800-446-2671 (in the United States & Canada)

DAN's Medical Information Line at (919) 684-2948 (800-446-2671 in the United States and Canada) is available weekdays from 9 a.m. to 5 p.m. Eastern Time (1400-2200 Greenwich Mean Time). Also, divers can make non-emergency medical inquiries through DAN's website www.diversalertnetwork.org.

When divers have questions about their health and how such questions may affect their diving, if they need to find a dive physician in their area, or if they have questions on medicines and diving, or diving after surgery, DAN's medical information specialists are there to help. The Medical Information Line and DAN's website are designed to allow callers to talk to a specially trained diving medical technician about non-emergency diving safety and health concerns. If divers need assistance in answering a question, DAN medics have the resources of DAN's senior medical staff, DAN's on-call physicians, diving researchers at Duke University Medical Center's F.G. Hall Hypo-Hyperbaric Center and other experts in dive medicine.

In some cases, DAN may refer callers to a diving medical specialist in their region for further evaluation. DAN's Medical Department received 12,692 information calls in 1997. Since its beginnings more than 18 years ago, DAN has helped more than 136,000 callers through these telephone services. E-mail inquiries have been increasing as well: almost 2,000 messages were answered in 1997.

DAN's dive safety and health research projects include Project Dive Exploration, the Flying After Diving studies and the Diving with Diabetes project.

■ DAN Dive Health and Safety Research

DAN's Research Department is dedicated to the study of diving health issues. Research is conducted at F.G. Hall Hypo-Hyperbaric Center at Duke University Medical Center and in the field through Project Dive Exploration, Doppler field studies and the Diving with Diabetes projects. DAN conducts important research on medical issues affecting recreational diving.

Diabetes and Diving Project

In 1996, DAN Research began a project to determine the relative safety of people diving with insulin-requiring diabetes. Approved by Duke University Medical Center's institutional review board, this project was launched in 1997 with trips to UNEXSO (the Underwater Explorers Society), Freeport, Bahamas, and to Cozumel, Mexico. In 1998, DAN made two trips on liveaboard dive vessels: one trip with Peter Hughes Diving, Inc. to Bay Islands, Honduras, and a second with the Aggressor Fleet Ltd. to the Cayman Islands. To date, 275 dives have been collected from 23 divers with insulin-requiring diabetes. Bayer Corporation and Can Am Care have supported this project with equipment and supplies. In addition, dive operators who are DAN Sponsors have helped support the project. The study is testing guidelines for blood glucose monitoring and collecting data on blood glucose levels before and after diving.

Flying After Diving Study

One of DAN's most ambitious research programs is using volunteers for studies in flying after diving. The experiment, which simulates various dive profiles and a subsequent flight at the maximum commercial airline cabin altitude (8,000 feet / 2,438 meters), is being conducted jointly by DAN and F.G. Hall Hypo-Hyperbaric Center. The goal is to develop guidelines for recreational divers for safe intervals between diving and flying aboard a commercial airliner.

Project Dive Exploration

Project Dive Exploration (PDE) took its pilot year in 1997-98. PDE uses recording dive computers to collect information on dive profiles. The goals: to create a database of both safe dives, and dives that result in DCI; this helps provide insight into the behavior, dive profiles and characteristics of recreational divers associated with DCI.

DAN's Doppler Field Studies

Ongoing for the past 10 years, DAN Doppler studies have been incorporated as a part of PDE. This work seeks to estimate the relationship of Doppler-detected bubbles to the dive profile.

U.S. Navy / DAN Survey of Recreational Divers

The U.S. Navy asked DAN for assistance in conducting a survey of recreational divers to obtain information about demographics, experience and diving habits. In early 1998, a randomly selected group of DAN members received a survey form.

The Navy has new low-frequency sonar called SURTASS LFA (Surveillance Towed Array Sonar System Low Frequency Active). Like the sonar in current use, safe operating limits must be determined. This particular sonar may be audible for many miles, so the potential for incidental exposure is greater than with current sonar.

The Navy set out to find sonar levels that would not cause problems in the recreational community, and conducted studies involving non-military-trained sport divers. The Navy's aim was to determine how representative the subjects are of the sport diver population: its link to DAN came in the form of DAN's development and implementation of a survey form sent to recreational divers.

In addition, this survey data will give the Navy an idea of the medical conditions present in sport divers, which may have to be taken into consideration in setting safe sonar operating limits.

Other Projects

Other major projects with which DAN personnel are involved take place at Duke's F.G. Hall Hypo-Hyperbaric Center. These include a NASA-funded study to determine how exercise and microgravity affect decompression illness in astronauts during "space walks," or extravehicular activity (EVA). This is in preparation for the construction of the International Space Station. There are military-funded projects to study dive computers, a diving database and oxygen-enhanced breath-hold diving.

This research requires the use of specialized hypo-hyperbaric scientists and physicians, software development and technical staffing. DAN projects are privately funded through DAN membership and dive industry support. Without DAN, many important questions about recreational diving safety would not only remain unchallenged, but unanswered.

■ DAN Support to the Dive Medical Community

Through DAN's Recompression Chamber Assistance Program, DAN provides training and financial support to recompression chambers throughout the Caribbean and other popular dive destinations in order to ensure that they remain in operation and properly staffed. This program complements DAN's biannual dive medical courses for physicians, nurses and paramedics to educate the international medical community on the proper care and treatment of injured divers.

In 1996, DAN once again broke new ground in the field of dive injury treatment and insurance, by creating a Diving Preferred

DAN offers a Recompression Chamber Assistance Program to help educate and maintain hyperbaric chambers and a Diving Preferred Provider Network to help manage the costs of treatment.

Provider Network (DPPN) of hyperbaric chambers to help manage the costs of recompression treatment and make it easier for hyperbaric facilities to receive payment for their services.

■ DAN Oxygen First Aid Training

For scuba instructors and dive enthusiasts, DAN offers the world's most popular oxygen first aid program, begun in 1991. Until DAN developed its oxygen training program and line of oxygen equipment, many injured divers did not benefit from emergency oxygen.

DAN founded the world's most popular oxygen first aid program, launched in 1991.

More than 72,000 divers and more than 8,000 diving professionals have been trained under this program.

As of January 1999, 72,628 divers and 8,124 diving professionals have been trained under this program. DAN also distributes a line of specialized oxygen delivery systems to treat injured divers.

For years DAN has strongly advocated the ready availability of emergency oxygen in diving injuries. In 1996, the U.S. Food and Drug Administration (FDA) reaffirmed its policy on the use of emergency oxygen without a prescription. In the state of Florida, divers certified as oxygen providers can now purchase oxygen and emergency oxygen equipment. DAN was instrumental in influencing these decisions. Lowering the barrier to access of oxygen was another step by DAN to ensure that injured divers would have emergency oxygen available when needed.

■ DAN On-Line – http://www.diversalertnetwork.org

DAN's Web Site on the World Wide Web provides a wealth of information on scuba health and safety and the many benefits of DAN membership. You can get answers to frequently asked dive medical questions, find a DAN retail Sponsor near you, sign up for DAN membership, order DAN products and more.

■ DAN Research On-Line – http://jshaldane.mc.duke.edu

DAN's Research Department has a Web site to communicate information on DAN research — particularly Project Dive Exploration, Flying After Diving and Diabetes and Diving. Interested participants can, at no cost, download software for collecting information about dive profiles and diving injuries.

DAN America Membership Services

In addition to supporting diving's only 24-hour diving emergency hotline, DAN members receive a number of valuable benefits, including emergency travel assistance, a subscription to award-winning *Alert Diver* magazine, DAN's "Dive and Travel Medical Guide" and dive and travel discounts.

DAN members are also eligible for affordable dive accident insurance and the exclusive DAN Tag™, diving's medical emergency ID, and the DAN Dog Tag, modeled after the popular military dog tag.

As of October 1998, approximately 195,000 members support DAN in the United States, the Caribbean, Canada and Mexico, plus an

DAN Dive Accident Insurance

Master Plan	Plus Plan	Standard Plan
Total Protection, including DAN TravelAssist: $260,000	Total Protection, including DAN TravelAssist: $170,000	Total Protection, including DAN TravelAssist: $145,000
Depth Limits: None	Depth Limits: 130 feet	Depth Limits: 130 feet
Price: $35/year‡	Price: $30/year‡	Price: $25/year‡
Coverage: $125,000 (lifetime) for decompression illness and in-water injuries*	Coverage: $50,000 (lifetime) for decompression illness*	Coverage: $45,000 (lifetime) for decompression illness*
$15,000 for accidental death and dismemberment	$10,000 for accidental death and dismemberment	
$15,000 for permanent total disability	$10,000 for permanent total disability	
$1,500 accommodations**		
$1,000 airline ticket**		
$2,500 lost dive equipment**		

‡ Plus the price of DAN membership

** If the loss was a result of being injured in a dive accident.

* For more detailed information on DAN insurance, please call DAN Member Services at (800) 446-2671, 9 a.m.-5 p.m. Eastern Time, Monday-Friday.

additional 58,000 members of International DAN affiliates. DAN America members receive the following dive and travel benefits.

■ DAN *TravelAssist*

One of the automatic benefits of membership with Divers Alert Network is DAN *TravelAssist*. This service provides up to $100,000 emergency medical evacuation assistance for *any* injury or illness — dive-related or not — incurred at least 50 miles from home by a DAN member or a DAN family member.

■ *Alert Diver* Magazine

DAN members receive a subscription to award-winning *Alert Diver* magazine, the only publication dedicated to diving safety and health.

■ DAN 'Dive and Travel Medical Guide'

New DAN members receive a copy of DAN's "Dive and Travel Medical Guide," a valuable reference on treating common diving and travel injuries and illnesses.

■ DAN Dive Accident Insurance

DAN members are eligible for three different levels in insurance — the Master, Plus and Standard Plans — in addition to DAN membership. DAN's Master Plan, in combination with membership benefits, offers up to $260,000 of protection for divers and travelers.

DAN pioneered dive accident insurance in 1987; and in 1992 DAN launched medical evacuation assistance member benefits. These

Only DAN members may purchase the DAN Tag, the first emergency ID tag created exclusively for divers.

moves helped fill a medical and financial need not being met by any other organization at the time, giving DAN members valuable additional benefits. Before these DAN programs, divers could be saddled with large medical bills, because most health insurance would not cover some or all of the charges associated with a diving injury. This issue still exists for some divers, and DAN strives to help bridge this gap.

Because membership records are kept in one secure location at DAN, only DAN can verify membership benefits and insurance coverage right away, and make arrangements for timely evacuation and recompression treatment.

■ DAN Dive Safety and Health Products

DAN members receive a special price on all DAN products. DAN's product line includes a variety of books and videos on the subject of dive safety and health, as well as emergency oxygen equipment and diver first aid kits. DAN's Product Listing, displaying these and other DAN products, is available in every issue of *Alert Diver* magazine. Select products are also available on DAN's website.

■ DAN Tags

In 1995, DAN introduced the first medical ID tag created exclusively for divers — the **DAN Tag™**. Each clip-on tag is personalized with vital membership, medical and contact information in the unlikely event of a diving emergency. Only DAN members can purchase the DAN Tag. A portion of DAN Tag sales goes directly to support DAN's Diving Emergency Hotline and DAN dive research. As of November 1998, more than 33,000 DAN tags are in use. In December 1998, DAN introduced the **DAN Dog Tag**. Modeled after the popular military dog tag, the front is imprinted with DAN's familiar logo and the Diving Emergency Hotline number. The tag's midsection allows space to imprint a diver's name and DAN member number.

■ DAN 24-Hour Diving Emergency Hotline with Immediate Insurance Verification

Dive and travel medical emergencies can happen any time. Callers to DAN's 24-Hour Diving Emergency Hotline can reach experienced medical professionals who are specially trained to handle dive and travel medical emergencies *at any time*, day or night.

With DAN's exclusive record-keeping system, DAN member emergency medical evacuation assistance and dive accident insurance policy records are kept in one central secure location at DAN. As a DAN member, if you (or your friend, spouse or physician) call DAN's Hotline with a diving emergency, DAN can verify membership benefits and insurance coverage right away and make arrangements for timely evacuation and/or recompression treatment.

■ DAN Membership Discounts

DAN members are eligible for special discounts on DAN products and other services. Check *Alert Diver* magazine for the most recent offers or call DAN's Member Services Department at (800) 446-2671.

Introduction to Scuba Injuries – Section 1

Focus on Decompression Illness and Fatalities

This edition of DAN's *Report on Decompression Illness and Diving Fatalities* is based on data gathered in the calendar year 1997 on treated cases of decompression illness (DCI) and on confirmed fatalities. Published in 1999, it is referred to throughout as "the report," and is the 11th annual report published by DAN.

The report is divided into two major sections: the first focuses on diving injuries resulting from DCI; the second section, beginning with section 6.0 (Page 62), discusses fatalities involving recreational scuba divers. DAN's injury database now contains data on 4,889 cases of DCI treated for the past 10 years, 3,960 cases since 1990.

DAN's injury database now contains data on 4,889 cases of DCI treated over the past 10 years.

Decompression Illness *(DCI)* Defined

Decompression illness, or DCI, is a general term used to describe a broad spectrum of signs and symptoms of diseases caused by excess inert gas in tissue, or dysbaric injuries, related to scuba diving. Arterial gas embolism (AGE) and decompression sickness (DCS) are the conventional terms used to describe two different and specific types of DCI injuries.

Arterial gas embolism, or AGE, is caused by gas bubbles that have entered the arterial system, generally by air passing through the walls of the lung alveoli into the arterial vessels. AGE can result after breathing compressed gas followed by voluntary breath-holding; or it can result from a pathological condition, which traps air in the lungs while ascending to the surface. Symptoms of AGE are usually immediate in onset and commonly involve changes in the level of consciousness, paralysis or other cerebral symptoms.

Decompression sickness, or DCS, is a syndrome caused by bubbles of inert gas formed within the tissues after diving. DCS usually results from a short deep dive or a prolonged exposure to breathing compressed gas at depths greater than 20 feet / 6.1 meters. Symptoms may be confined to the musculoskeletal system and consist of joint or muscle pain. In recreational diving, DCS more often involves the central nervous system with symptoms, usually in the spinal cord, of numbness, tingling, muscular weakness and other complaints.

Why DAN Collects This Data

DAN collects dive injury data to obtain details on how decompression sickness and arterial gas embolism occur in recreational scuba divers. This information is also valuable in determining trends or

changes in the types of diving injuries and symptomatology that occur, as well as how emergency treatment (recompression therapy) affects the outcome.

This information can then be used to help inform and educate the diving community — from recreational scuba divers, to dive researchers, to medical doctors.

DAN collects data on dive injuries in an effort to help inform and educate the diving community – from recreational divers, to dive researchers to medical doctors.

Data from previous years have been combined into three-year increments. This is done to show the consistency of trends or changes in trends by allowing the reader to compare yearly results.

How DAN Does It

Each year DAN contacts hyperbaric facilities worldwide in order to determine the number of cases reported for treatment of DCI. The total number of DCI cases reported for the years 1995-1997 are shown in Table 1.1 (Page 15). Appendix H (Pages 126-127) shows totals for the years 1986-1994.

Decompression Illness Cases

Table 1.1 shows a breakdown of decompression illness cases by conventional (generally accepted) diagnoses:

- **Type I decompression sickness**, or DCS-I — only skin bends, fatigue, lymphatic signs, or joint or muscle pain is present;
- **Type II decompression sickness**, or DCS-II — any neurological and cardiorespiratory symptoms are present;
- **Arterial gas embolism**, or AGE — symptoms are presumably caused by gas emboli in the arterial system.

For more information on symptoms of DCI, see section 4 (Page 44). These diagnoses are assigned by the treating physician at the hyperbaric facility. Table 1.1 represents the total number of cases treated in 1997 separated according to records received from the DAN region in which treatment occurred. The Caribbean Basin is included in the totals for the Southeastern United States.

Table 1.2 (Pages 15-17) represents the total number of cases by diagnosis reported to DAN in 1997, separated by regions and states within that region. The Caribbean Basin is represented separately in this table.

The numbers for 1997 represent the total number of treated cases, reported from 31 states, 18 countries and four U.S. territories — U.S. Virgin Islands, Puerto Rico, Guam and the Marshall Islands. Although there may be some non-U.S. or Canadian residents treated at U.S. facilities, the number of treated cases for any given year refers primarily to U.S. and Canadian residents who are treated in U.S. or Caribbean chambers and U.S. residents who are treated in non-U.S. chambers.

TABLE 1.1 *Total Reported Number of Cases by Year and Region* **

1997	Other*	SW	NW	MW	GU	PA	NE	SE+	TOTALS
DCS-I	5	56	3	27	14	9	38	70	222
DCS-II	9	73	53	26	49	20	64	304	598
AGE	0	15	2	6	6	2	2	35	68
No classification assigned	0	0	0	0	0	0	4	80	84
TOTALS	**14**	**144**	**58**	**59**	**69**	**31**	**108**	**489**	**972**

1996	Other*	SW	NW	MW	GU	PA	NE	SE+	TOTALS
DCS-I	5	38	18	13	29	5	37	115	260
DCS-II	14	73	36	24	68	22	44	248	529
AGE	0	18	2	5	4	9	5	47	90
No classification assigned	0	0	0	4	0	0	22	30	56
TOTALS	**19**	**129**	**56**	**46**	**101**	**36**	**108**	**440**	**935**

1995	Other*	SW	NW	MW	GU	PA	NE	SE+	TOTALS
DCS-I	1	70	21	9	30	0	34	97	262
DCS-II	7	95	40	20	89	15	56	316	638
AGE	0	20	1	2	11	4	2	37	77
No classification assigned	0	0	0	0	0	72	15	68	155
TOTALS	**8**	**185**	**62**	**31**	**130**	**91**	**107**	**518**	**1,132**

** Includes all foreign countries and U.S. military personnel (these cases involved active-duty military personnel who were diving recreationally and treated in military chambers).*

+ SE includes Caribbean basin.

*** See Table 1 (below) for abbreviations and breakdown of reporting regions.*

TABLE 1.2 *Total Number of Cases Treated and Reported in 1997 by Region*

Southwest Region (SW)	DCS-I	DCS-II	AGE	NC*	TOTALS
Arizona	5	3	0	0	8
California	50	69	14	0	133
Utah	1	1	1	0	3
TOTALS	**56**	**73**	**15**	**0**	**144**

Northwest Region (NW)	DCS-I	DCS-II	AGE	NC*	TOTALS
Oregon	2	7	0	0	9
Washington	1	46	2	0	49
TOTALS	**3**	**53**	**2**	**0**	**58**

** NC = No classification -- Cases where the chamber did not distinguish among diagnoses.*

TABLE 1.2 *(continued)* *Total Number of Cases Treated and Reported in 1997 by Region*

Midwest Region (MW)	DCS-I	DCS-II	AGE	NC*	TOTALS
Illinois	10	11	2	0	23
Indiana	2	1	0	0	3
Kentucky	2	0	0	0	2
Michigan	4	3	0	0	7
Minnesota	0	4	0	0	4
Ohio	5	3	0	0	8
Wisconsin	4	4	4	0	12
TOTALS	**27**	**26**	**6**	**0**	**59**

Gulf Region (GU)	DCS-I	DCS-II	AGE	NC*	TOTALS
Colorado	1	5	3	0	9
Louisiana	1	4	0	0	5
Missouri	1	9	0	0	10
Oklahoma	0	2	0	0	2
Texas	11	29	3	0	43
TOTALS	**14**	**49**	**6**	**0**	**69**

Pacific Region (PA)	DCS-I	DCS-II	AGE	NC*	TOTALS
Hawaii	8	14	2	0	24
Guam	1	6	0	0	7
TOTALS	**9**	**20**	**2**	**0**	**31**

Northeast Region (NE)	DCS-I	DCS-II	AGE	NC*	TOTALS
Connecticut	0	6	0	4	10
Maine	3	3	0	0	6
Maryland	3	9	0	0	12
Massachusetts	8	19	2	0	29
New Jersey	15	12	0	0	27
New York	6	8	0	0	14
Pennsylvania	2	3	0	0	5
Rhode Island	0	1	0	0	1
Virginia	1	3	0	0	4
TOTALS	**38**	**64**	**2**	**4**	**108**

* *NC = No classification — Cases where the chamber did not distinguish among diagnoses.*

TABLE 1.2 *(continued)* *Total Number of Cases Treated and Reported in 1997 by Region*

Southeast Region (SE)	DCS-I	DCS-II	AGE	NC*	TOTALS
Alabama	1	2	0	0	3
Florida	42	143	17	47	249
Georgia	11	6	0	0	17
North Carolina	3	0	0	33	36
South Carolina	1	9	0	0	10
Tennessee	1	1	0	0	2
TOTALS	**59**	**161**	**17**	**80**	**317**

Caribbean Basin	DCS-I	DCS-II	AGE	NC*	TOTALS
Bahamas	0	7	0	0	7
Barbados	1	1	0	0	2
Belize	0	22	3	0	25
Bermuda	0	1	1	0	2
Bonaire	0	0	1	0	1
Cayman	6	16	6	0	28
Cuba	0	1	0	0	1
Mexico	2	60	3	0	65
Puerto Rico+	0	1	1	0	2
Saba	0	4	0	0	4
St. Thomas+	0	8	3	0	11
Turks & Caicos	2	22	0	0	24
TOTALS	**11**	**143**	**18**	**0**	**172**

+ *U.S. Territories*

Other	DCS-I	DCS-II	AGE	NC*	TOTALS
Fiji	1	0	0	0	1
Palau	3	7	0	0	10
Saudi Arabia	1	1	0	0	2
Thailand	0	1	0	0	1
TOTALS	**5**	**9**	**0**	**0**	**14**

* *NC = No classification — Cases where the chamber did not distinguish among diagnoses.*

Collection of Cases for the DAN Database

Divers Alert Network utilizes a network of 270 hyperbaric chambers in the United States, Canada and around the world to report decompression illness injuries. The DAN network is now divided into eight regions, each overseen by a Regional Coordinator (see Page 4). In 1997, the eighth region was added: it includes Florida and the Caribbean Basin and has a separate regional coordinator. Data for the 1997 year includes information from this newest region.

Diving Accident Reporting Forms (DARFs) are sent to DAN for further verification before their final inclusion in DAN's injury database.

The number of individuals with DCI who did not seek medical attention, or who were not referred for treatment, is unknown.

Regional Coordinators assist DAN in the collection of *Diving Accident Reporting Forms* (DARFs) from their area chambers. Injured divers use DARFs to document their injury with DAN. (This year, 1997, is the last reporting year to use the standard DARF.*) Regional Coordinators also assist in directing injured divers to the nearest qualified area medical centers for evaluation and treatment.

DAN is initially informed of a diving injury through phone calls, but in order to enter the cases into its database, DAN receives a completed *Diving Accident Reporting Form*. Each year DAN solicits hyperbaric treatment centers to participate in the reporting program. Of the 972 cases of treated DCI reported to DAN by phone in 1997, DAN received only 634 DARFs reporting these incidents.

The names and identifying personal information on the DARFs are confidential and not available to anyone outside DAN's Medical and Research Departments. Injury data are not used to imply individual fault or blame but to determine the cause of scuba injuries and any common trends in certain outcomes. The number of individuals with DCI who did not seek medical attention, or who were not referred for treatment, is unknown.

In many instances there is a significant delay from completion of a treatment and the receipt of the DARF by DAN. Only DARFs for cases treated in calendar year 1997 received by DAN before July 1, 1998, are included in this report. Divers treated at more than one hyperbaric facility are only counted once, unless they were injured a second time.

When an injured diver's case is received at DAN, it is logged into a tracking database. DAN's medical information specialists then contact the diver by phone to follow up on all cases that meet the inclusion criteria (see Page 19). Cases are not followed up if the person involved could not be located or the case is in litigation. Divers with residual symptoms at the time of follow-up are contacted by DAN three months after the injury or until they no longer have residual symptoms.

** Note: In 1998 DAN revised the* Diving Accident Reporting Form (DARF) *into a more standardized reporting format known as the* Diving Injury Report Form, *or* DIRF. *The DIRF has been developed to describe symptoms more accurately, enhance diagnosis, assist in classification and reduce uncertainty about the diagnosis of DCI.*

Inclusion Criteria Explained

Of the 634 DARFs received at DAN, 452 met the criteria for inclusion in the DAN injury database. This represents 71 percent of the cases where DARFs were received at DAN.

To be included in the DAN database, a case must meet the following criteria.

Inclusion Criteria

- The diver must be a recreational scuba diver using scuba and breathing compressed air only. Mixed-gas divers are included in a separate database (see below).
- The only professionals included are scuba instructors or divemasters providing recreational dive instruction.
- If treated in a U.S. chamber, both U.S. and Canadian residents are included.
- If treated in a non-U.S. chamber,* only U.S. residents are included.
- Final diagnosis by the treating hyperbaric physician must be decompression illness.
- Cases must be received by July 1 of the following year for each collection year (e.g., July 1, 1998, for the 1997 reporting year).
- Each individual must have been contacted after treatment by the DAN medical staff.

A total of 178 cases were excluded from the DAN injury database for the reasons cited below.

Exclusion Criteria

- The injured diver was a commercial, occupational or scientific diver (n = 39);
- If treated in a U.S. chamber, the injured diver was not a resident of the U.S. or Canada; or, if treated in a non-U.S. chamber,* the diver was not a U.S. resident (n = 38);
- DCI was not diagnosed; i.e., the injury was non-DCI, such as ear barotrauma, pulled muscle, marine life envenomation (n = 44);
- The diver used surface-supplied air or was breath-hold diving (n = 3);
- There were some cases in which no follow-up was possible by DAN medical staff because of a legal concern, or because the person was unable to be located (n=24);
- Sections 1-5 (Pages 13-61) include the 452 cases in which compressed air was the breathing gas while diving.

Mixed-Gas Divers

Thirty divers are included in a separate technical diver database (Appendix E, Page 117). They are analyzed separately because they utilize a different breathing gas and may use different techniques and procedures than divers using air.

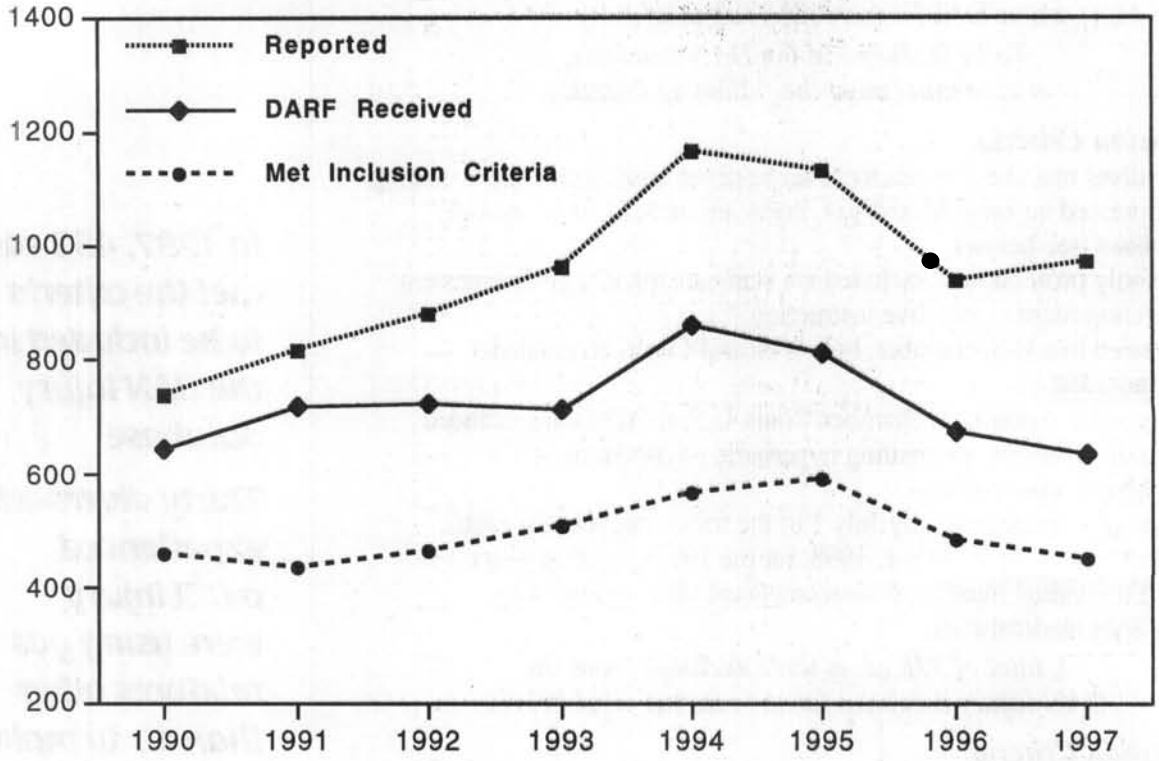
Graph 1.1 (next page) shows dive injury reporting and collection trends since 1986. The top line indicates the total number of cases reported to DAN by telephone (972 in 1997); the middle line represents the total number of DARFs sent to DAN for review (634); the bottom line represents the total number of cases which met the criteria for inclusion in DAN's 1997 injury database (452).

In 1997, 452 cases met the criteria to be included in the DAN injury database.

Thirty divers who experienced a DCI injury were using gas mixtures other than air to make technical dives. They are discussed in Appendix E.

** Canadian citizens treated in Canada are not reported to DAN.*

Graph 1.1 ***Total Number of Cases Reported, Received, and Completed by DAN***



Database Cases

The "n" represents the population size or the number of injured divers depicted in a table or graph.

Percentages were rounded to the nearest tenth.

In a number of the 452 injury cases in which air was breathed and which meet the inclusion criteria in 1997, respondents did not fully complete the reporting forms. In the event a question is not answered, tables in the report may show a *frequency missing* = "x," where "x" is the number of cases in the database that did not respond to that question.

The "n" is a statistical notation that represents the sample size or, in this case, the number of injured divers depicted in that table or graph. Percentages were rounded to the nearest tenth.

The location of the dive injury for the 452 cases analyzed in this report are contained in Tables 1.3 and 1.4. These 452 cases represent those cases that met the inclusion criteria.

Table 1.3 (Page 21) shows the number of cases broken down by country (n = 452); and Table 1.4 on the following page represents the number of injuries treated in the U.S. states and territories (n = 279).

Tables 1.3 and 1.4 show where the injury occurred and do not necessarily indicate where the treatment was conducted.

Table 1.3 *Injuries by Country and U.S. Territories*

Country	Frequency	Percentage
Cuba	1	0.2
Indonesia	1	0.2
Jamaica	1	0.2
Barbados	2	0.4
Bermuda	2	0.4
Fiji	2	0.4
Honduras	2	0.4
Palau	2	0.4
Saba	2	0.4
British Virgin Islands	3	0.7
Antilles	4	0.9
Bonaire	5	1.1
Turks & Caicos	5	1.1
Canada	8	1.8
Cayman Islands	14	3.4
Bahamas	18	4.0
U.S. Territories	**20**	**4.4**
Belize	24	5.3
Mexico	77	17.0
USA	**259**	**57.3**
TOTAL	**452**	**100.0**

Tables 1.3 and 1.4 show where diving injuries occurred but do not necessarily indicate treatment locations.

Table 1.3 shows the number of cases broken down by country.

Table 1.4 *Injuries by U.S. States & Territories*

State	Frequency	Percent
Alabama	1	0.4
Alaska	1	0.4
Colorado	1	0.4
Illinois	1	0.4
Kentucky	1	0.4
Minnesota	1	0.4
Missouri	1	0.4
New Mexico	1	0.4
Ohio	1	0.4
Rhode Island	1	0.4
Utah	1	0.4
West Virginia	1	0.4
Wyoming	1	0.4
Arizona	2	0.7
Connecticut	2	0.7
Indiana	2	0.7
Maryland	2	0.7
Massachusetts	2	0.7
Virginia	2	0.7
New York	3	1.0
South Carolina	3	1.0
Marshall Islands*	3	1.0
Pennsylvania	4	1.4
Texas	4	1.4
Puerto Rico*	4	1.4
Guam*	5	1.8
Michigan	6	2.2
US Virgin Islands*	8	2.8
North Carolina	9	3.2
Wisconsin	9	3.2
New Jersey	13	4.6
Hawaii	17	6.1
Washington	27	9.7
California	37	13.2
Florida	102	36.6
TOTALS	**279**	**100.0**

* *US Territories*

Table 1.4 represents the number of injuries treated in the U.S. states and territories.

Tables 1.3 and 1.4 show where diving injuries occurred but do not necessarily indicate treatment locations.

Summary

■ Each year, DAN's medical services refer hundreds of callers with suspected DCI to hyperbaric facilities. Not all callers follow the advice of the medical specialists or seek medical treatment.

■ DAN's Medical Department made follow-up contacts with all of the hyperbaric chambers in its referral network to verify and collate the total number of DCI injuries that were treated in 1997.

■ In 1997, 972 cases of DCI were treated by chambers that report their numbers to DAN. Of these cases, 634 Diving Accident Reporting Forms (DARFs) were sent to DAN. In 1997, 452 cases met the inclusion criteria and were added to the injury database.

■ This report on 1997 data represents 47 percent of the total number of divers treated by reporting hyperbaric facilities. Since the first annual *Report* published in 1987, between 42 to 62 percent of all divers treated have been included in DAN's injury database (see Pages 18-19).

■ Collection efforts continue to improve and provide an effective method of collecting injury forms for review.

In 1997, 452 cases met the inclusion criteria and were added to the injury database.

To report an injury, a fatality or a near-miss in diving, call DAN's Medical Department at +1-919-684-2948 or 800-446 2671.

Divers Alert Network
The Peter B. Bennett Center
6 West Colony Place
Durham, NC 27705

Injured Diver Characteristics – Section 2

The number of injuries reported in the age 45-49 category has increased, which may reflect an aging diving population.

This section includes various characteristics, such as age, sex, diving experience and certification level of the divers in DAN's 1997 database on divers with decompression illness (DCI). While DAN seeks to identify trends from year to year, the degree to which injured divers reflect the general diving population is unknown. DAN is attempting to learn more about the general diving population through surveys to DAN members and Project Dive Exploration.

The data for the years 1996-1997 are presented individually, while the earlier data are presented in three-year increments.

Age Distribution in Divers with DCI

Table 2.1 shows that for 1997, there was a decrease in the number of incident of DCI reported in the age 25-29 category. The number of DCI injuries in the 15-19 age category, however, has increased and is at its highest percentage. The number of injuries in the age 45-49 category has also increased, which may reflect an aging diving population.

Table 2.1 *Age Distribution of Injury Cases by Percentage*

Age	1997	1996	93-95	90-92	87-89
10-14	0.4	0.4	0.8	0.6	0.5
15-19	4.9	2.7	3.2	2.9	2.8
20-24	7.5	7.2	8.5	9.0	9.4
25-29	12.4	19.5	17.1	18.4	22.4
30-34	18.8	18.4	19.8	23.0	22.9
35-39	20.8	20.5	18.8	21.2	16.8
40-44	12.2	15.5	14.4	12.8	12.4
45-49	12.8	6.6	8.7	6.8	6.4
50-54	6.6	4.8	5.0	2.9	3.3
55-59	2.2	3.1	2.5	1.1	1.7
60-64	0.7	1.0	0.6	1.1	1.4
>=65	0.7	0.2	0.6	0.2	0.0
TOTALS	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Table 2.2 *Gender of 1987-1997 Injury Cases by Percentage*

Gender	1997	1996	93-95	90-92	87-89
Female	31.0	36.0	29.8	27.0	24.2
Male	69.0	64.0	70.2	73.0	75.8
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Gender of Injury Cases

Injured female divers represent 31 percent of divers treated in the 1997 database. An increasing number of women were injured up to 1996, but this trend stopped in 1997.

Diver Experience in Injury Cases

The column headings in Table 2.3 (Page 26) show the total numbers of lifetime dives reported by the divers, while the row headings show the number of years of diving. The body of the table shows the number of divers in each category.

Looking at total numbers of dives, the trend is a decreasing number of accidents with increasing numbers of dives until the 121+ number of dives category is attained. This may represent the fact that divers injured early in their diving careers (0-20 dives) either stop diving or become more cautious. Divers who dive a lot (121+ dives) have more accidents probably because they dive more and are likely diving more aggressively.

With females, the increase in years of experience seems to show decreasing numbers of cases of DCI in general. The same trend is seen for male divers into the 18- to 19-year category. The increase in the 20- to 21-year category is due to the fact that it includes almost all the divers with 121+ dives.

Overall, dive reporting reflects that females have experienced decompression illness after fewer years of diving and after fewer dives.

In general, injured male divers have been diving for more years than injured female divers.

Table 2.3 *Number of Lifetime Dives and Years Diving Among Injured Divers in 1997*

Male	Total Lifetime Dives							
Years Diving	0-20	21-40	41-60	61-80	81-100	101-120	121+	TOTAL
0-1	50	17	5	3	3	1	4	83
2-3	9	6	7	3	3	2	10	40
4-5	1	5	2	2	5	1	13	29
6-7	3	2	3	2	3	1	17	31
8-9	1	0	4	2	2	1	10	20
10-11	1	1	0	0	1	1	9	13
12-13	1	1	1	0	0	0	13	16
14-15	0	0	0	0	0	1	16	17
16-17	0	0	0	0	0	0	8	8
18-19	0	0	1	0	0	0	7	8
20-21	0	0	0	0	0	1	46	47
TOTALS	66	32	23	12	17	9	153	312

Female	Total Lifetime Dives							
Years Diving	0-20	21-40	41-60	61-80	81-100	101-120	121+	TOTAL
0-1	48	7	0	1	1	0	0	57
2-3	8	8	5	0	1	2	4	28
4-5	5	1	1	1	3	1	8	20
6-7	1	0	2	1	1	0	2	7
8-9	0	1	1	0	0	0	2	4
10-11	1	2	0	0	1	0	7	11
12-13	0	0	0	0	0	0	1	1
14-15	0	0	0	0	0	0	5	5
16-17	0	0	0	0	0	0	0	0
18-19	0	0	0	0	0	0	1	1
20-21	0	1	0	0	0	0	5	6
TOTALS	63	20	9	3	7	3	35	140

The number of female divers with less than two years of experience decreased in 1996 and 1997, from a high reported in 1995.

Injuries by Years of Diving Experience

Table 2.4 (Page 27, top) shows a comparison of DCI injuries with years of experience. According to this table, more female divers report injuries earlier in their careers. Most DCI injuries in male divers occur with less than 10 years' diving experience.

The number of injured female divers with less than two years of diving experience decreased in both 1996 and 1997, from a high reported in 1995. The biggest changes in 1997 were in the more experienced female divers: 17 percent of injuries occurred in those divers with 10 years or more experience in diving. There was a decrease of 12.8 percent in the number of female injuries in the six- to nine years' range of experience.

Table 2.4 *Percentage of Injured Divers by Years of Experience*

Years Diving	Sex	1997	1996	93-95	90-92	87-89
< 2 Years	Male	26.7	27.5	27.8	26.5	19.2
	Female	40.7	41.4	48.4	46.8	39.0
2 to 5 Years	Male	22.1	26.8	26.9	31.6	28.1
	Female	34.3	27.0	31.0	32.9	32.8
6 to 9 Years	Male	16.3	14.2	13.2	12.7	15.6
	Female	7.9	20.7	10.9	9.9	18.2
≥ 10 Years	Male	34.9	31.4	32.3	29.2	37.1
	Female	17.1	10.9	9.3	10.4	9.9

Table 2.5 *Certification Level of 1987-1997 Injury Cases by Percentage*

	1997 Cases			Combined Percentages				
Certification	Male	Female	Totals	1997	1996	93-95	90-92	87-89
Student	1	5	6	1.3	1.9	2.4	1.9	1.3
Basic/Open Water	120	83	203	44.9	47.2	48.0	49.7	49.7
Advanced	109	35	144	31.9	28.4	27.3	25.4	25.9
Divemaster	42	6	48	10.6	9.5	8.1	8.0	5.6
Instructor	30	8	38	8.4	7.7	11.1	10.4	10.9
Commercially Trained	0	0	0	0.0	0.2	0.2	0.3	1.3
Other	8	2	10	2.2	3.9	2.3	2.8	1.8
None	2	1	3	0.7	1.2	0.6	1.3	1.2
Unknown	0	0	0	0.0	0.0	0.0	0.2	2.3
TOTALS	**312**	**140**	**452**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Certification Levels in Diving Injuries

As seen in Table 2.5 (above), the percentage of students in the injured population remains low. One would expect that injuries among student divers would be minimal as diver depth, time in the water, diving frequency, and style or nature of diving are closely supervised. While there are variations from year to year, there appears to be no trend for *Basic* and *Open-Water* certification categories or for the categories *Divemaster, Instructor, Commercially Trained or Other.*

An upward trend for injuries in advanced divers continues through the 1997 data. The number of injured divers who reported having no certification decreased slightly but has remained relatively constant over the years.

An upward trend for injuries in advanced divers continues through the 1997 data.

Diving Intensity in Injured New Divers

New Divers are defined as having been diving for less than two years; infrequent divers have 20 or fewer lifetime dives. These two sets of divers accounted for nearly 40 percent of all injured divers in 1997, a figure largely unchanged from the previous three years of reporting.

Fourteen divers were excluded from the "Outside Limits" category because they were not using any method to calculate or plan their dive. A large percentage of new divers engaged in repetitive diving (66.3 percent) and diving to depths of 80 feet / 24 meters or deeper (52.0 percent).

Table 2.6 ***New Diver (Less than Two Years' Experience) Profile Traits by Percentage***

Traits	1997	1996	93-95	90-92	88-89
Repeat Dive	66.3	60.9	60.5	61.6	55.2
Diving ≥ 80 fsw	52.0	51.0	57.4	60.8	52.1
Square Dives	39.5	49.5	56.3	50.9	55.2
Rapid Ascent	39.5	40.6	34.6	35.6	42.2
Last Dive ≥ 80 fsw	19.3	21.4	26.5	30.3*	0.0
Outside Limits	17.7	16.7	13.2+	22.6	23.4
No Table/Computer Use	4.1	6.8	7.0**	-	-
	n=171	*n=192*	*n=656*	*n=528*	*n=192*

** 1992 only*
*** 1994 and 1995 only*
+ refers to 638 cases

Current Medical History in Divers With DCI

Table 2.7 (Page 29, top) shows the organ system affected in those divers who reported a current medical problem unrelated to their DCI. Unfortunately, there are no details in the database regarding the exact nature of the disease or condition.

The percentage of injured divers without current medical problems has remained fairly constant since 1990.

The number of divers experiencing injuries who reported having asthma was 1.5 percent for 1997, which is similar to 1996 (1.4 percent). Table 2.8 (Page 29) shows that the percentage of injured divers without current medical problems has remained fairly constant since 1990. A current health problem is defined as having occurred in the two months preceding the dive injury. In 1997, 77 percent reported no problems.

Previous Medical Problems in Divers with DCI

Table 2.9 (Page 30, top) shows that the spectrum of previous medical problems among injured divers has not changed significantly since

Table 2.7 ***Number of DCI Cases and Current Medical Information for the Years 1988-1997***

Problem	1997	1996	93-95	90-92	88-89
None	348	371	1259	994	462
Spine/Back	14	19	61	51	29
GI/Abdomen	14	18	46	37	13
Muscl/Skel System	10	10	33	54	23
Mental/Emotion	8	8	25	27	12
Asthma	7	7	36	21	11
Limb/Joint DCS	7	5	19	16	5
Chest-lung	3	6	27	37	13
Cir/Blood	3	2	18	12	9
Neuro/Nerv System	2	4	14	17	4
Chest-heart	2	2	15	12	10
Eye	1	2	12	6	5
Brain	1	0	3	2	-
No response	0	0	1	1	0
Other	43	37	144	125	87
TOTALS	**463***	**491***	**1713***	**1412***	**683***

** Some divers reported multiple health problems.*

Table 2.8 ***Percentage of Divers Without Current Health Problems***

Current	1997	1996	93-95	90-92	87-89
Frequency	348	371	1259	994	636
Percent	77.0	76.8	76.1	75.0	68.5

1993. A previous health problem may have been reported at any time longer than two months prior to the injury.

Table 2.10 (Page 30) shows that since 1993 about half of the divers experiencing DCI reported no previous medical problems, with little evidence of a trend over the years.

Physical Fitness in Divers With DCI

Divers with DCI were asked to evaluate their degree of physical fitness, and as seen in Table 2.11 (Page 30, bottom), about 90 percent said they were physically fit. Unfortunately, there were no objective criteria used to substantiate these claims (frequency and type of daily exercise, and similar data) so it is difficult to draw any conclusion as to how physical fitness affects the likelihood or severity of DCI.

Table 2.9 *Number of DCI Cases and Previous Illness for the Years 1988-1997*

Problem	1997	1996	93-95	90-92	88-89
None	248	270	867	664	313
Other	75	57	263	203	108
Muscl/Skel System	42	50	160	169	83
GI/Abdomen	39	53	142	129	69
Spine/Back	36	29	131	130	58
Limb/joint DCS	22	23	87	101	25
Asthma	19	14	66	49	30
Chest-lung	11	11	44	57	28
Mental/Emotion	10	7	22	22	5
Chest-heart	8	9	42	34	17
Eye	6	13	43	25	11
Neuro/Nerv System	6	3	27	33	8
Brain	3	3	14	12	5
Cir/Blood	3	3	19	17	10
No Response	0	0	2	1	0
TOTALS	**528**	**545**	**1929**	**1646**	**770**

Table 2.10 *Percentage of Divers Without Previous Health Problems*

Current	1997	1996	93-95	90-92	87-89
Frequency	248	270	867	664	444
Percent	54.9	56.0	52.0	46.0	47.8

Table 2.11 *Percentage of Injured Divers Who Reported Being Physically Fit*

Sex	1997	1996	93-95	90-92	88-89
Male	89.4	88.0	91.3	91.2	91.0
Female	90.7	90.2	90.3	88.3	87.0
TOTAL	**89.8**	**88.8**	**91.0**	**90.4**	**90.0**

Medication Use in Injured Divers

Tables 2.12 and 2.13 show the types and percentages of prescription medications and over-the-counter (OTC) medications commonly used and reported by recreational divers.

Most medications reported appear to be prescribed and to have been used on a long-term basis. Non-prescription medications are generally used on an as-needed basis to minimize a health condition and permit diving, such as in the use of an anti-motion sickness medication.

In past reports, DAN has shown the number of divers who reported recreational drug use. Given the social and legal implications of such usage, it is likely that these numbers do not reflect the true incidence. With no independent measures of recreational drug use among injured divers, this category has been deleted from the study.

Table 2.12 ***Medication Use in Injury Cases***

Year	Prescription Use		Nonprescription Use	
	Frequency	Percent	Frequency	Percent
1997	141	31.2	57	12.6
1996	167	34.6	71	14.7
1993 - 1995	476	28.8	249	16.5
1990 - 1992	372	28.0	234	20.0
1988 - 1989	151	23.6	96	16.3

Table 2.13 ***Common Medications Used in Injured Divers by Percentage***

Medication	Percent
Birth Control	19
Psychotropics	12
Analgesics/non-steroidal anti-inflammatories	11
Decongestants	9
Antihistamines	8
Antibiotics	8
Heart	6
Estrogens	6
Anti-motion sickness	4
Thyroid	4
Antiulcer	3
Migraine	3
Antihypertensives	2
Weight loss drugs	2
Rhinorrhea agent	1
Insulin	1
Cholesterol-lowering	1

Alcohol Use In Injury Cases

Table 2.14 (below) shows that both the time of alcohol use and the number of divers abstaining has remained fairly constant over the reporting years.

Diarrhea may lead to dehydration, which is thought to be a risk factor in DCI.

About 2 percent of divers reported drinking just before diving or between dives. The number of drinks consumed during these time periods is not available. Because alcohol is a diuretic, it tends to dehydrate divers. In addition, alcohol may affect performance and thinking, but there are no measures of this in the database.

Nausea and hangover (symptoms of headache, nausea) are two likely outcomes of excessive alcohol consumption, but only 19 divers (4.2 percent) reported either symptom on the day of the dive, as shown in Table 2.15 (below). It cannot be automatically assumed, however, that these symptoms were alcohol-related.

Table 2.15 shows that seven cases of pre-dive diarrhea were reported, which represents 1.5 percent of all DCI cases. Diarrhea may lead to dehydration, which is thought to be a risk factor in DCI.

Table 2.14 *Percentage of Alcohol Use*

Time of Use	1997	1996	93-95	90-92	88-89
Night before	36.3	37.3	39.2	38.1	41.8
Pre-dive	1.3	0.8	1.2	1.4	1.7
Between dives	0.6	0.4	1.2	1.5	2.3
Post-dive	16.4	14.5	15.5	14.5	13.5
None	54.9	56.3	53.2	55.2	49.7
	n=452	*n=483*	*n=1664*	*n=1358*	*n=659*

**Some divers engage in drinking at more than one time before and/or after diving.*

Table 2.15 *Number of Injury Cases with Nausea, Hangover, and Diarrhea*

Sex	Nausea	Hangover	Diarrhea
Male	6	7	2
Female	6	0	5
Totals	**12**	**7**	**7**

Summary

- Male divers reporting DCI tend to have more years of diving experience and more total lifetime dives than injured female divers.
- Although there have been slight changes each year, the overall percentage of injury reported for each level of diving certification has remained relatively stable.
- Seventy percent of injured divers are male.
- The majority of male divers with DCI are between 25 and 50 years old.
- Divers with fewer than 20 lifetime dives or who had been diving for less than two years accounted for 40 percent of the DCI cases.

Seventy percent of injured divers are male.

To report an injury, a fatality or a near-miss in diving, call DAN's Medical Department at +1-919-684-2948 or 800-446 2671.

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Dive Profile / Incidents – Section 3

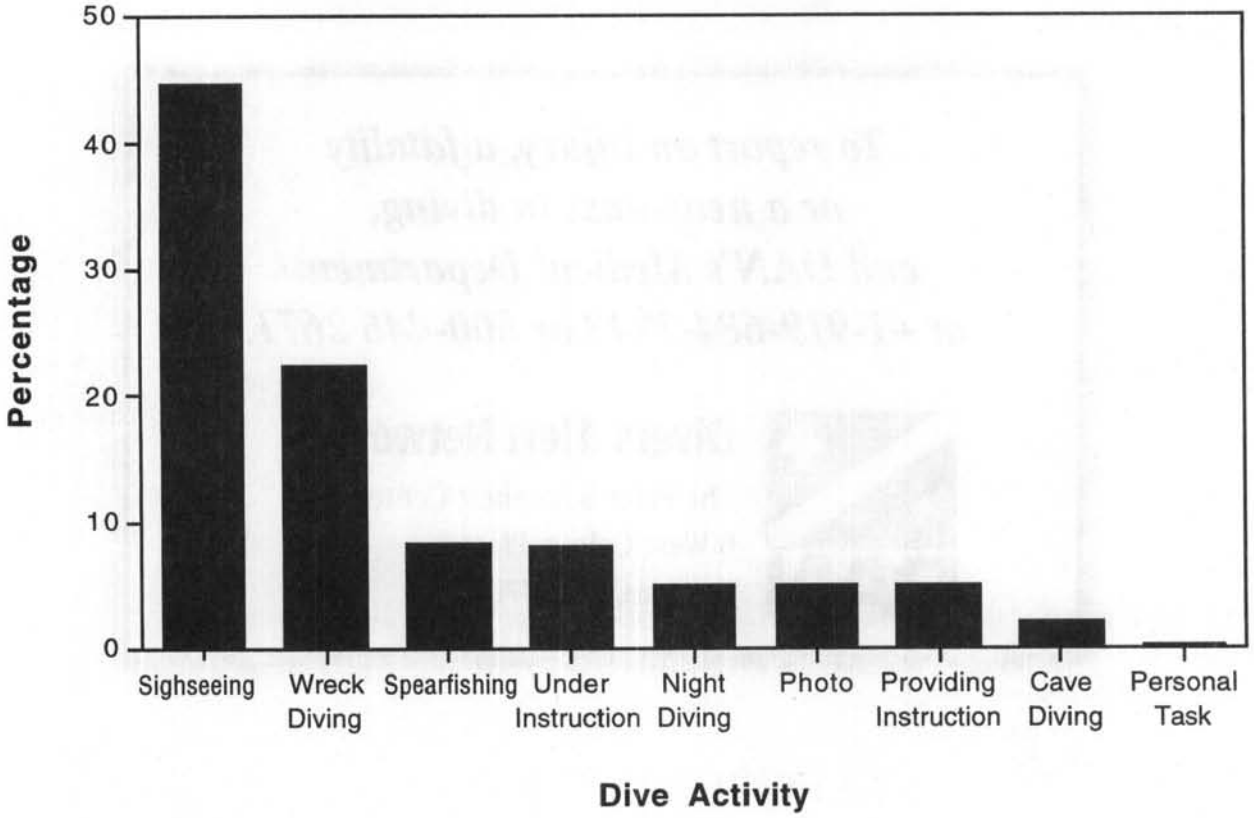
44.7 percent of all injuries occurred while sightseeing; wreck diving was the second most common activity associated with diving injuries.

Dive Activities

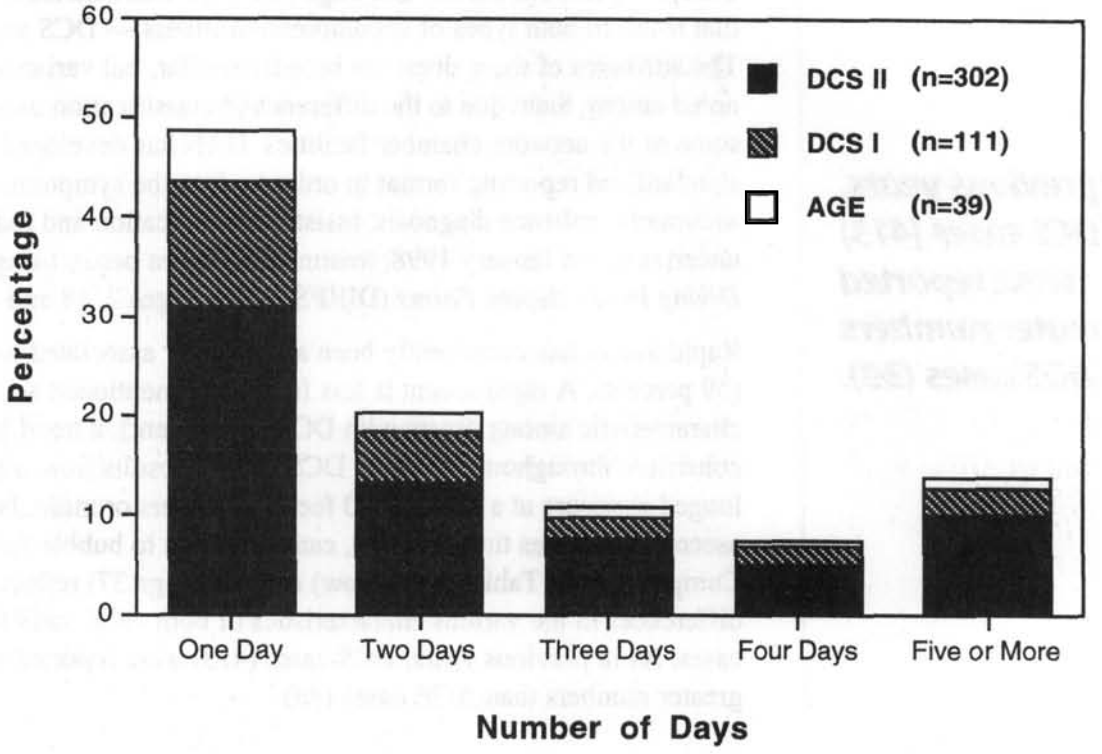
The dive profile section identifies the type of underwater activity being performed and various attributes of the dives at the time of a DCI incident. The dive profile information is limited and can only be considered in relation to the various attributes of dives recorded by DAN.

The breakdown of diver activity has generally remained the same for the last three years. A total of 44.7 percent of all injuries occurred while sightseeing; 22.3 percent of diving injuries occurred while the diver was wreck diving (Graph 3.1, below). Few injuries occurred among instructors teaching scuba (4.9 percent). Students receiving instruction represented 8.0 percent of all injury cases. The incidence of DCI associated with cave diving was again low (2 percent) in the 1997 data. Divers conducting personal tasks (which includes such activities as boat cleaning) totalled .2 percent of DCI injuries in 1997.

Graph 3.1 *Primary Dive Activity*



Graph 3.2 *Number of Days of Continuous Diving in DCI Injuries*



Length of Dive Series

Graph 3.2 (above) shows that in 1997 nearly half of all injured divers suffered their injuries during a single-day dive program (48.7 percent). The single-day diving group illustrates two general characteristics:

- 76.4 percent of the injuries occurred in divers making more than 20 dives per year; and
- 61.8 percent had completed a dive in the last 30 days.

Fifty-one percent of those divers with two years or less diving experience — or 20 or fewer dives — were injured on the first day of diving. Fifty-nine percent of all arterial gas embolism injuries occurred in single-day diving, compared to 65.5 percent in 1996.

Overall, more injuries occurred after the first day of diving (48.7 percent). Approximately 51 percent of injuries were reported after two or more days of diving, and 13 percent of these were associated with a series of dives or five days or more of diving.

In the small group of divers who made dives over five or more days, 87 percent experienced symptoms involving the nervous system. This is a higher fraction of neurological symptoms than for any group. This may represent an increased risk of DCS II in diving this long, or it could mean these divers ignored DCS I and kept diving until DCS II occurred.

Fifty-one percent of those divers with less than two years of diving experience were injured on the first day of diving.

Dive Characteristics of DCS and AGE

Tables 3.1 and 3.2 (below and Page 37) show characteristics of dives that result in both types of decompression illness — DCS and AGE. The attributes of these dives are broadly similar, but variations are noted among them due to the difference in classification used by some of the network chamber facilities. DAN has developed a more standardized reporting format in order to describe symptoms accurately, enhance diagnosis, assist in classification and reduce uncertainty. In January 1998, treatment facilities began using these *Diving Injury Report Forms* (DIRFS — see Pages 2, 18 and 47).

As in previous years, DCS cases (413) were reported in greater numbers than AGE cases (39).

Rapid ascent has consistently been a risk factor associated with AGE (59 percent). A rapid ascent is less frequently mentioned as a dive characteristic among divers with DCS (23 percent), a trend fairly consistent throughout the years. DCS usually results from a prolonged exposure at a depth of 20 feet / 6.1 meters or more, but rapid ascents, as well as time at depth, can contribute to bubble formation. Comparisons of Tables 3.1 (below) and 3.2 (Page 37) reflect the differences in the various characteristics of both AGE and DCS cases. As in previous years, DCS cases (413) were reported in greater numbers than AGE cases (39).

Table 3.1 ***Dive Attributes Among Injured Divers Diagnosed with DCS (Type I and II) by Percentage***

Attribute	1997	1996	93-95	90-92	87-89
Within Limits	85.2	80.7	92.4+	**	**
No Decompression	82.3	85.9	82.4	80.0	78.5*
Multilevel	72.4	64.2	57.0	64.1	51.9*
≥ 80 fsw	71.2	64.5	71.4	64.5	74.6*
Repeat Dive	68.3	66.4	62.2	68.2	52.9
Multi Day	52.3	54.1	52.2	48.7	51.0*
Exertion	49.6	58.4	57.6	49.3	29.8
Single Day	47.7	45.9	47.7	51.3	53.3
Current	43.8	50.1	50.8	50.5	40.7
Single Dive	31.7	33.6	37.7	32.6	32.7*
< 2 yr. Experience	28.3	32.0	32.0	30.9	26.1
Square	27.6	34.6	37.6	35.8	42.8*
Fatigue	26.6	28.2	30.6	34.5	34.1
Rapid Ascent	22.8	24.0	23.6	21.9	24.3
Buoyancy	15.3	15.5	12.5	11.6	13.6

**These percentages are from 1989 only.*
***The blank fields for the category "Within Limits" from 1987-1993 indicate a change in analysis method.*
+These percentages are from 1994 and 1995 only.

DCS Characteristics

Dive characteristics most frequently associated with DCS cases in DAN's injury database are repeat multilevel dives, deeper than 80 fsw / 24 msw. A high percentage of divers had more than two years of dive experience.

AGE Characteristics

The typical AGE incident occurs within the limits of the table or computer used and as part of a single dive and single-day series. A total of 59 percent of individuals with AGE claimed to have made a rapid ascent, a much higher percentage than in cases of DCI. Cases of AGE tend to involve a lower percentage of multilevel and deep dives to greater than 80 feet / 24 meters when compared to those diagnosed as DCS. Also more buoyancy problems were noted with AGE cases. Most AGE incidents continue to occur on the first dive of the day (59 percent).

Most AGE incidents continue to occur on the first dive of the day.

Assigning the diagnosis of AGE or DCS may be influenced by a knowledge of the dive profile and is usually taken into account in AGE cases: a short dive with minimal gas (nitrogen) uptake weighs in favor of AGE rather than DCS.

Table 3.2 ***Dive Attributes of Divers Diagnosed with AGE by Percentage***

Attribute	1997	1996	93-95	90-92	87-89
No Decompression	100.0	91.4	90.6	68.1	92.3*
Within Limits	84.6	77.6	84.3	90.4	80.0
Single Dive	66.7	67.2	77.7+	**	**
Multilevel	61.5	36.2	38.2	41.7	35.5*
Single Day	59.0	65.5	54.3	67.9	48.6
Rapid Ascent	59.0	56.9	51.2	56.3	52.0
< 2 yr. Experience	48.7	29.3	43.5	35.7	49.3
Exertion	46.2	48.3	58.5	41.9	19.3
Multi Day	41.0	34.5	45.7	32.1	46.2*
Current	38.5	36.2	53.0	45.5	32.6
Square	38.5	63.8	55.1	58.3	55.8*
≥ 80 fsw	35.9	58.6	50.3	49.4	46.2*
Repeat Dive	33.3	32.8	25.1	29.9	29.3
Buoyancy	30.8	32.8	28.4	28.6	21.3
Fatigue	12.8	24.1	17.6	13.1	29.3

**These percentages are from 1989 only.*
***The blank fields for the category "Within Limits" from 1987-1993 indicate a change in analysis method.*
+These percentages are from 1994 and 1995 only.

A small group of divers were considered separately because they chose to dive without using a computer or dive tables. The category "Within Limits" represents divers who were diving within their computer or table limits. Additionally, in reports filed in earlier years, there were fewer computer users; and divers at this time may have been considered "Outside Limits" if they were not within both computer and table limits. In this report, as with the last two years' reports, each group — computer divers and table divers — is considered separately, which explains the blank fields in Tables 3.1, 3.2, 3.4 and 3.5.

Methods of Dive Planning in Injured Divers

Approximately 59.5 percent (n=269) of the divers with DCI reported using computers, while 37 percent (n=169) reported using tables.

Assigning the diagnosis may be influenced by a knowledge of the dive profile: a short dive with minimal gas uptake weighs in favor of AGE rather than DCS.

Table 3.3 ***Computer, Table, and Neither Computer/Table Users with Decompression Illness by Percentage***

	Computer Users				
	1997	**1996**	**93-95**	**90-92**	**87-89**
DCS I	29.0	28.7	28.5	23.5	30.0
DCS II	65.8	64.5	65.9	69.6	62.0
AGE	5.2	6.8	5.6	6.7	8.0
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
	n = 269	*n = 265*	*n =916*	*n = 626*	*n = 251*

	Table Users				
	1997	**1996**	**93-95**	**90-92**	**87-89**
DCS I	17.2	22.6	21.0	15.4	17.5
DCS II	69.2	58.5	65.4	67.6	63.2
AGE	13.6	18.9	13.6	17.0	19.3
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
	n = 169	*n = 195*	*n = 678*	*n = 735*	*n = 668*

	Neither Computer or Table			
	1997	**1996**	**1995**	**1994**
DCS I	28.6	13.0	14.3	20.0
DCS II	57.1	69.6	80.0	65.7
AGE	14.3	17.4	5.7	14.3
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**
	n=14	*n=23*	*n = 35*	*n = 35*

Three percent (n=14) used neither in planning their dives, fewer than in previous years. The distribution of DCS cases between DCS I and DCS II was similar for both computer divers and table divers. This distribution has remained static since 1989.

Table 3.3 reflects the classical diagnosis breakdown for computer, table, and neither (divers who used neither dive computers nor tables). The percentage of AGE cases has decreased in all three groups. About 14 percent of injured table divers experienced AGE, compared to 5 percent of injured computer divers. One conclusion suggested by these data is that rate-of-ascent indicators on dive computers are better than judgment methods (e.g., not ascending faster than your bubbles) at helping keep divers from ascending too quickly. Of the divers in the database who did not use any method of dive planning, 57 percent had Type II DCS, 29 percent had DCS I, and 14 percent were diagnosed with AGE.

Tables 3.4 and 3.5 (below and Page 40) show the attributes of both table and computer divers. By their own admission, 6.3 percent of computer divers performed dives where the no-decompression limits for their computer were violated. The percentage of table divers violating their tables was 16.5 percent. The 14 individuals who used neither computers or tables were excluded from Tables 3.4 and 3.5. This exclusion, as previously noted, has caused the percentage of injured divers outside limits to decrease since 1993.

Of the divers in the database who did not use any method of dive planning,

- ***57 percent had Type II DCS,***
- ***29 percent had DCS I and***
- ***14 percent were diagnosed with AGE.***

Table 3.4 ***Attributes of Computer Divers From 1987-1997 by Percentage***

Attribute	1997	1996	93-95	90-92	87-89
Within Limits	93.7	92.1	92.5+	**	**
Repeat Dive	81.4	84.5	80.7	69.0	63.7
Multilevel	79.9	75.6	76.1	78.8	71.4
≥ 80 fsw	77.7	73.2	78.3	73.1	86.5
Multi Day	54.3	57.0	52.1	48.6	53.2*
Exertion	48.3	59.6	58.7	48.4	29.9
Single Day	45.7	43.0	47.9	51.2	50.6
Current	41.3	50.6	50.6	48.9	43.8
Fatigue	27.2	30.3	28.7	32.5	31.0
Decompression	20.4	18.5	21.6	24.5	32.7
Outside Limits	6.3	7.9	16.1	40.9	39.4

**These percentages are from 1989 only.*

***The blank fields for the category "Within Limits" from 1987-1993 indicate a change in analysis method.*

+These percentages are from 1994 and 1995 only.

Table 3.5 *Attributes of Table Divers From 1987-1997 by Percentage*

Attribute	1997	1996	93-95	90-92	87-89
Within Limits	83.4	81.5	84.7+	**	**
Repeat Dive	76.5	79.0	71.7	58.8	51.0
Multilevel	66.1	54.4	34.7	45.9	45.3*
≥ 80 fsw	54.1	58.5	54.3	53.7	63.4*
Single Day	53.0	51.3	47.2	54.6	53.2
Exertion	50.8	61.0	58.0	49.7	27.4
Multi Day	47.0	50.8	52.8	44.7	49.1*
Current	46.4	51.3	50.5	50.5	37.8
Fatigue	23.0	27.7	30.4	31.4	34.2
Outside Limits	16.5	18.5	16.2	25.6	28.7
Decompression	14.8	11.8	11.2	13.2	20.2

**These percentages are from 1989 only.*

***The blank fields for the category "Within Limits" from 1987-1993 indicate a change in analysis method.*

+These percentages are from 1994 and 1995 only.

In about 20 percent of DCI cases, computer divers had made dives requiring decompression stops; table divers performed decompression stops in 15 percent of DCI cases. Multilevel dives were performed by 80 percent of computer divers and by 66 percent of table divers. This difference is expected, because dive computers favor multilevel diving in their algorithms without the bottom-time limitations imposed by tables.

Table 3.6 *Attributes of Divers Using Neither Computer nor Tables by Percentage*

Attribute	1997	1996	1995	1994
Multilevel	78.6	56.5	62.9	57.1
Current	78.6	43.5	42.9	88.6
≥ 80 fsw	64.2	39.1	54.3	65.7
Repeat Dive	64.2	47.8	62.9	51.4
Exertion	57.1	52.2	48.6	62.9
Single Day	57.1	52.2	40.0	57.1
Multi Day	42.9	52.2	60.0	42.9
Decompression	28.6	21.7	14.3	2.9
Fatigue	21.4	26.1	37.1	28.6
	n=14	*n=23*	*n = 35*	*n = 35*

The 14 divers who used neither computers nor tables tended to follow their buddies or divemasters. These individuals made dives deeper than 80 feet / 24 meters in 64.2 percent of cases, made multiday dives in approximately 43 percent of cases and made repetitive dives in 64.2 percent of cases (Table 3.6, Page 40).

The 1997 DAN database revealed that computer users were more experienced divers and had been diving more often and for a greater number of years than table users. There was a small difference between groups in the number of divers who ran out of air —1.3 percent of table users and 1.5 percent of computer users.

DAN's 1997 database revealed that computer users were more experienced divers, and had been diving more often and for a greater number of years than table users.

Equipment

Scuba diving is an activity that requires knowledge and familiarity with the equipment used and adequate maintenance of that equipment. Correct equipment function and knowing how to use it safely are crucial to safe diving. Of the cases outlined in the 1997 report, 15.3 percent reported equipment problems (Table 3.7, below).

Table 3.7 ***Number of Injured Cases with Equipment Problems***

Equipment	DCS	AGE	Total
Unfamiliar Equipment	17	0	17
Regulator	10	4	14
BC Vest	10	2	12
Weight Belt	4	3	7
Inflator Hose	6	0	6
Other	3	3	6
DC Computer	5	0	5
Dry Suit	2	0	2
Contaminated Air	0	0	0
TOTALS	**57**	**12**	**69**

This year, for the first time, the major equipment problem was the diver's lack of familiarity with the gear and its use.

Over the years, injuries associated with equipment problems have remained low in number. A report of an equipment problem does not necessarily mean that equipment failure caused the incident but merely that the diver recognized a problem. This year the major equipment problem was found *not* to be an actual equipment failure but rather the diver's lack of familiarity with the gear and its proper use. Those divers with DCI who reported an equipment problem were most likely to have reported trouble with a regulator or

buoyancy control device. Divers with AGE primarily reported equipment difficulties with their regulator, weight belt or buoyancy control device. Some divers listed other problems that influenced their dive profile. These included depth or pressure gauge problems (1), problems with the scuba tank (3) and problems with masks (2).

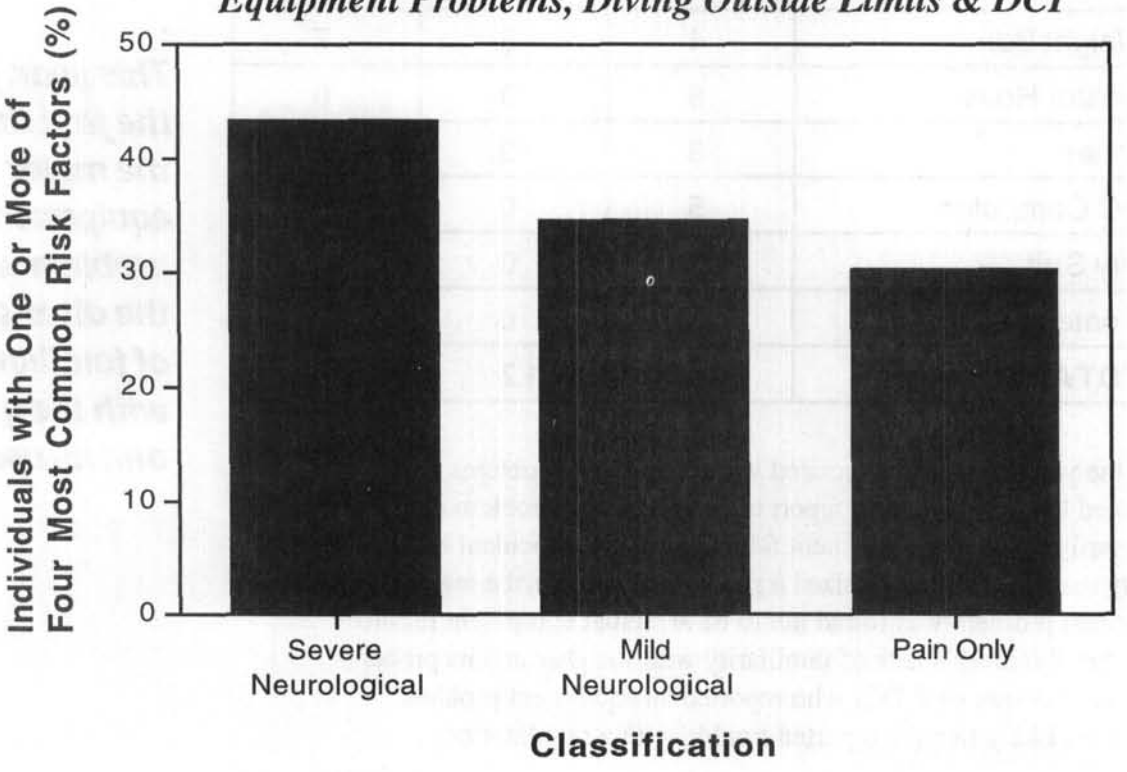
Over half of the divers with AGE and equipment difficulties reported a problem with their regulator, air supply or unfamiliarity with their gear.

Common Risk Factors Associated with DCI

The four most common risk factors associated with DCI were: rapid ascent, buoyancy problems, equipment problems and diving outside the limits of one's computer or dive tables.

Thirty-six percent of the divers in the 1997 injury database reported one or more of these factors. Graph 3.4 (below) shows the percentage of these individuals separated into symptom classification. A brief explanation of this classification system of symptoms includes: **Severe neurological** — unconsciousness, paralysis, visual disturbance, difficulty walking, semi-consciousness, bowel problem, speech disturbance, bladder problem, convulsions; **mild neurological** — numbness, weakness, dizziness, decreased skin sensation, reflex change; **pain / skin / non-specific** — pain, headache, extreme fatigue, nausea, itching, rash, restlessness, muscle twitch, hemoptysis (spitting blood). Section 4 contains an additional explanation of this classification system (see Table 4.1, Page 45, and Table 4.5, Page 48), and includes a listing of non-specific and ambiguous symptoms as well.

Graph 3.3 ***Association of Rapid Ascent, Buoyancy and Equipment Problems, Diving Outside Limits & DCI***



Summary

■ AGE-related cases are characterized by single-day, single-dive, square profiles and are associated with a rapid ascent in 59 percent of all AGE injuries. A rapid ascent is less frequently mentioned as a dive characteristic among divers with DCS (23 percent), a trend fairly consistent throughout the years.

■ DCS-related cases are characterized by divers who tend to have more experience and engage in multiday, deeper, repetitive dives.

■ Most injured divers stated they stayed within the limits of their tables or computer, but 3.0 percent of all divers reported not using any dive planning procedure.

■ Injured divers who reported using dive computers were less likely to be diagnosed with AGE (arterial gas embolism) than divers using tables or neither method.

■ Among injured divers, computer users tend to be more experienced divers and now make up 59.5 percent of the divers reporting injuries this year.

■ Equipment problems were found in 15.3 percent of the DCI cases. A lack of familiarity with equipment characterized the largest percentage (24.6 percent) of these cases. This underscores the importance of proper use and maintenance of dive equipment.

Injured divers who reported using dive computers were less likely to be diagnosed with AGE compared to DCS than divers using tables or neither method.

To report an injury, a fatality or a near-miss in diving, call DAN's Medical Department at +1-919-684-2948 or 800-446 2671.

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Symptoms of DCI – Section 4

Frequency of Occurrence of Symptoms

Table 4.1's shaded totals rows show the sum of the rows it is describing. For information on the number of injured divers represented in each category see Table 4.5.

The frequency of symptoms of decompression illness (including all cases of both AGE and DCS) is shown in Table 4.1 (Page 45). DCI consists of different signs and symptoms developing over a period of time. As a result, the total occurrence of all symptoms (n=1,638) is greater than the total number of cases (n=452).

As in recent years, pain was the most frequent first symptom of DCI, occurring in approximately 35 percent of the cases, while 81 percent of divers with DCI experienced pain at some time in their illness. Numbness also occurred at some point in 78.5 percent of DCI cases.

Note that in Table 4.1, Total Occurrence Percent is the percent of all symptoms (1,638), not a percent of all divers.

The "First Symptom" column shows the number of divers who noted any given symptom first out of the possible symptoms listed. As a result, the number of first symptoms equals the number of cases. The "Total Occurrence" column shows all occurrences of each symptom. Since most divers reported more than one symptom, the total occurrence is greater than the number of divers.

The development of neurological symptoms when only pain or fatigue were present initially suggests that neurological or severe symptoms might be preventable through early treatment with emergency oxygen.

For the purpose of this analysis, neurological symptoms are classified in this report as either serious or mild. While weakness could be classified as a serious symptom, it is an ambiguous term since it can be interpreted as either unmistakable motor weakness, or a vague feeling of generalized malaise. Certain symptoms such as hearing loss and ringing in the ears, while serious, have not been listed as severe neurological symptoms because they can be manifestations of otic barotrauma and cannot be definitively ascribed to decompression illness. Similarly, difficulty breathing is ambiguous in that it may be a manifestation of anxiety, pulmonary barotrauma or water aspiration. Personality changes may be attributed to a number of different causes, but this symptom is too non-specific to be considered a definite symptom of DCS as recorded in DAN's injury forms.

Four percent of divers with DCI reported a severe symptom first, while 26 percent reported a severe symptom later. The eventual development of neurological symptoms when only pain or fatigue were present initially, as well as the progression from mild symptoms to severe ones, suggest that neurological or severe symptoms might be preventable through early treatment with emergency oxygen.

Table 4.1 *1997 Most Frequent Symptoms of Decompression Illness*

			First Symptom		Total Symptom Occurrence		
			N	% Cases	N	% Symptoms	% Cases
Neurological	Severe	Unconsciousness	6	1.3	18	1.1	4.0
		Paralysis	5	1.1	13	0.8	2.9
		Visual disturbance	3	0.7	28	1.7	6.2
		Difficulty walking	3	0.7	35	2.1	7.7
		Semi-consciousness	1	0.2	12	0.7	2.7
		Nystagmus	1	0.2	3	0.2	0.6
		Coordination decrease	0	0.0	3	0.2	0.6
		Bowel problem	0	0.0	3	0.2	0.7
		Speech disturbance	0	0.0	6	0.4	1.3
		Bladder problem	0	0.0	2	0.1	0.4
		Convulsions	0	0.0	1	0.06	0.2
Total Severe Neurological Symptoms			**19**	**4.2**	**124**	**7.6**	*
Neurological	Mild	Numbness	101	22.3	355	21.7	78.5
		Weakness	28	6.2	126	7.7	27.8
		Dizziness	22	4.9	107	6.5	23.6
		Decreased skin sensation	0	0.0	38	2.3	8.4
		Reflex change	0	0.0	5	0.3	1.1
Total Mild Neurological Symptoms			**151**	**33.4**	**631**	**38.5**	*
Total Neurological Symptoms			**170**	**37.6**	**755**	**46.1**	*
Pain/skin/		Pain	157	34.7	366	22.3	80.9
nonspecific		Headache	33	7.3	122	7.4	26.9
		Extreme fatigue	22	4.9	109	6.7	24.1
		Nausea	22	4.9	80	4.9	17.6
		Itching	13	2.9	33	2.0	7.3
		Rash	6	1.3	25	1.5	5.5
		Restlessness	6	1.3	30	1.8	6.6
		Muscle twitch	3	0.7	27	1.6	5.9
		Hemoptysis	0	0.0	4	0.2	0.8
Total Pain/Skin/Nonspecific Symptoms			**262**	**58.0**	**796**	**48.4**	*
Ambiguous		Personality change	2	0.4	9	0.6	1.9
		Hearing loss	1	0.2	3	0.2	0.6
		Ringing in ears	0	0.0	6	0.4	1.3
Cardiorespiratory		Difficulty breathing	5	1.2	28	1.7	6.1
Other		Disoriented	4	1.0	14	0.9	3.0
		Muscle ache/soreness	2	0.4	6	0.4	1.3
		Swelling	2	0.4	8	0.5	1.7
		Bleeding	1	0.2	1	0.06	0.2
		Ear blockage	1	0.2	1	0.06	0.2
		Stiffness	1	0.2	6	0.4	1.3
		Urge to cough	1	0.2	1	0.06	0.2
		Cold flashes	0	0.0	2	0.1	0.4
		Cramps	0	0.0	2	0.1	0.4
Total Ambiguous/CR/Other Symptoms			**20**	**4.4**	**87**	**5.5**	*
		Total	**452**	**100.0**	**1638**	**100.0**	*

• *There is no total percentage for the "% Cases Column". Multiple symptoms may have been present within individual cases among the 452 divers.*

Table 4.2 *Traditional Classification of DCS Symptoms*

DCS-I (only these occur)	DCS-II (any of these present)
Pain	Neurological
Fatigue	Cardiorespiratory
Skin	
Lymphatic	

Traditionally **decompression illness** (DCI) has been classified into:

- **arterial gas embolism** (AGE) — gas bubbles in the vascular (arterial) system due to pulmonary overpressurization; and
- **decompression sickness** (DCS) — the formation of gas within tissues and bloodstream after scuba diving. DCS has been further classified into Type I, or DCS I; and Type II, or DCS II (Table 4.2, above).

Table 4.3 *Conventional Disease Diagnosis by Percentage*

Final Diagnosis	1997	1996	'95-93	'92-90	'89-87
DCS-I	24.6	25.3	25.3	19.3	21.0
DCS-II	66.8	62.7	65.7	68.3	63.0
AGE	8.6	12.0	9.0	12.4	16.0
TOTAL	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

A diver who makes a shallow dive for a minute or two and then is observed to surface while holding his breath or making a panic ascent — after which he has a convulsion and loses consciousness — is more likely to have AGE than DCS.

The distributions of conventional diagnoses in Table 4.3 (below) show that the majority of DCI cases are DCS II, or cases with CNS symptoms. The differentiation between AGE and the two forms of DCS was previously believed to be important because the classification dictated the form of recompression treatment. This is no longer the case, at least in U.S. Navy treatment protocol.

It is possible to differentiate between these diagnoses: for example, a diver who makes a shallow dive for a minute or two and then is observed to surface while holding his breath or making a panic ascent — after which he has a convulsion and loses consciousness — is more likely to have AGE than DCS.

Alternatively, when a diver who has a deep-dive profile and enough time to develop a significant inert gas load experiences joint pain two hours after surfacing, that diver more likely has DCS.

In many instances, however, it is difficult to make an accurate differentiation because contributing factors, such as the rate of ascent or breath-holding, may not have been observed. Additionally, a diver may have had a depth-time profile sufficient to develop DCS and an ascent likely to produce AGE.

Since it is still widely used, the traditional classification as assigned by the treating physician is reported with individual symptoms.

Errors in Classification

Classification as DCS I, DCS II or AGE was made by the physician completing the DARF (Diving Accident Report Form), based on diver symptoms and the physician's own experience. However, in some cases it was noted that divers with reported neurological symptoms were classified as DCS I. In the traditional classification of DCS, the presence of any neurological symptom is DCS II by definition. There were 111 cases classified by the treating physician as DCS I, but a review of cases by physicians at Duke University Medical Center revealed that 62 had neurological complaints (49 mild, 13 severe) noted. This means that 56 percent of DCS I cases were misclassified.

There was a total of 379 divers who reported a neurological symptom at some time, 284 having mild symptoms and 95 having severe as defined in Table 4.1. A total, then, of 16.4 percent of all divers with any neurological symptom and 13.7 percent of divers with any severe neurological symptom were misclassified. Misclassification may have been due to the physician's lack of familiarity with the classification scheme or the diver's failure to report, or bring to the physician's attention, a neurological symptom not present or apparent at the time of treatment.

Difficulties in classifying symptoms into either AGE or DCS have led to the recent emphasis on individual symptoms or "symptom clusters" as better predictors of outcome than the traditional scheme.

Difficulties such as these have led to the recent emphasis on individual symptoms or "symptom clusters" as better predictors of outcome than the traditional scheme. Work to develop better outcome predictors following treatment continues. The classification into mild and severe symptoms outlined in Table 4.1 represents a preliminary approach. The new injury form, called the Diving Injury Report Form DIRF (see Pages 2,18 and 36), will incorporate the old classification (DCS I, DCS II, AGE) and give details of the symptoms, the onset of symptoms and relief of symptoms through treatment.

Despite the errors in classification, the reported numbers reflect the diagnosis assigned by the treating physician. The proportion of divers in each diagnostic category remains largely unchanged.

Table 4.4 ***Symptom Types Found in Traditional Classifications of DCI (Number of Cases)***

Symptom Type	DCS-I	DCS-II	AGE
Severe Neurological	13*	61	21
Mild Neurological	49*	219	16
Pain/Skin/Non-Specific	49	22	2
TOTALS	**111**	**302**	**39**

*Misclassification

Table 4.5 *Classification by Type of Symptom (Percentage)*

Symptom Type	1997 #	1997 %	1996	93-95	91-92	89-90
Any Severe	95	21.0	22.2	25.8	32.7	27.3
Only Mild	284	62.8	59.6	56.8	47.3	52.6
Pain/Sk/Non-Sp	73	16.2	18.2	17.4	20.0	20.1
TOTALS	**452**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
	n=452		*n=483*	*n=1664*	*n=902*	*n=850*

95 percent of divers with AGE became symptomatic within two hours, and 95 percent of those with DCS were symptomatic within 28 hours.

Table 4.5 classifies cases in three ways: severe if any severe neurological symptoms were reported; mild if no severe neurological symptoms were present; and pain only if no neurological symptoms (mild or severe) were stated.

Symptom Onset Time

Symptom onset time is shown in Table 4.6 (below). Because the distribution of onset times is not symmetrical, the typical onset time is best estimated by the median (time at which 50 percent of divers have become symptomatic), rather than the mean. Interestingly, the median onset times of DCS I and DCS II are similar.

As expected, the median onset time of AGE is significantly shorter. Ninety-five percent of divers with AGE became symptomatic within two hours; 95 percent of those with DCS were symptomatic within approximately 28 hours, while the median onset time was one hour.

Table 4.6 *Symptom Onset Time after Surfacing (hours): All Divers*

Classification	N	Mean	Standard Deviation	Median	95th Percentile Time*
DCS-I	111	7.0	14.7	1.0	28.0
DCS-II	302	5.9	11.7	1.0	27.0
AGE	39	0.7	4.5	0.02	2.0
All DCI	452	5.8	12.2	0.3	27.0

**Time after surfacing by which 95% of individuals have developed at least one symptom.*

Post-dive altitude exposure may cause DCS when none would have occurred otherwise. Onset times involving altitude exposure do not reflect the time course of the natural disease since the altitude exposure is a further provocation. After excluding all cases with altitude exposure, the data were analyzed and is displayed in Table 4.7 (see page 49, top). This shows that eliminating altitude exposure drops the median onset time for DCS I and DCS II. This probably means that altitude exposure causes symptoms, albeit later, when none would have occurred. The time for 95 percent of symptoms to develop was reduced when altitude exposures were eliminated in both DCS I and DCS II.

Table 4.7 *Symptom Onset Time after Surfacing (hours) Divers with Altitude Exposure Excluded*

Classification	N	Mean	Standard Deviation	Median	95% Time*
DCS-I	79	3.9	8.0	0.3	16.0
DCS-II	232	4.5	10.0	0.3	19.0
AGE	30	1.4	5.1	0.01	2.0
All DCI	341	4.0	9.3	0.2	20.0

**Time after surfacing by which 95% of individuals have developed at least one symptom.*

Table 4.8 *Percentage of Divers with Decompression Illness Symptoms Prior to Last Dive*

Sex	1997	1996	93-95	90-92	88-89
Male	17.0	18.1	17.1	16.9	13.4
Female	16.4	14.9	22.0	36.0	26.0
TOTAL	**16.8**	**17.0**	**18.6**	**22.1**	**16.5**
	n=452	*n=483*	*n=1664*	*n=1361*	*n=649*

Approximately 17 percent of all divers with DCI reported having experienced symptoms prior to their last dive.

Symptoms Prior to Last Dive

Seventy-six divers — 16.8 percent of all divers; 17 percent of males, 16.4 percent of females — reported having experienced symptoms of DCS before their last dive (Table 4.8, above).

The proportion of divers continuing to dive after symptom onset is similar to that of previous years. A distribution of the type and severity of symptoms experienced prior to the last dive is shown in Table 4.9 (below).

Table 4.9 *Symptom Classification of Divers Experiencing Symptoms Prior to Last Dive (Number of Cases)*

Symptom Category	Number	Percent (%)*
Severe Neurological	11	2.4
Mild Neurological	39	8.6
Pain/Skin/Nonspecific	26	5.8
TOTAL	**76**	**16.8**

** Percentages are of the total injury population.*

Divers Who Continued to Dive with Symptoms

Seventy-six individuals continued to dive with symptoms of DCI. Of these, 39 divers experienced mild neurological symptoms, primarily numbness in an extremity. Twenty-six had pain-only/non-specific symptoms, and an additional 11 had severe neurological symptoms. Of those with severe symptoms, five experienced visual disturbances, such as blurred vision or difficulty focusing, but continued to dive.

A diver who had a history of DCI made six dives in two days to depths of 70-80 fsw / 21-24 msw. This individual had symptoms after the first dive but continued to dive. This diver experienced visual disturbances, numbness in one hand and weakness and numbness in the right leg. The diver called for assistance 36 hours later and received treatment three days after the final dive. The diver received a U.S Navy Treatment Table 6 and had relief of all symptoms.

One diver made three dives after symptoms of fatigue and visual disturbances occurred.

Another diver made nine dives in five days to depths of 80 fsw / 24 msw. Symptoms occurred on the first dive of the fourth day. This individual made two additional dives after experiencing visual disturbances, numbness in legs and pain in the lower back. The diver received field first aid, including oxygen, aspirin* and oral fluids. At the hospital, the diver received oxygen, intravenous fluids, aspirin and steroids. The diver was treated with a U.S. Navy Treatment Table 6 six hours after the last dive and had complete relief of symptoms.

A diver made 10 dives in four days to 100 fsw / 30 msw. This individual made three dives after symptoms of fatigue and visual disturbances occurred. The diver received oral fluids and aspirin in the field and in the hospital, and steroids at the hospital. Treatment with a U.S. Navy Treatment Table 6 occurred 24 hours after the final dive. This diver received 10 additional hyperbaric treatments and had residual neurological symptoms for three weeks.

Another diver had visual disturbances, dizziness and shoulder weakness after two dives. Symptoms began after the first dive, but the diver made another dive to 170 fsw / 51.8 msw. The diver received oxygen and oral fluids in the field, and oxygen and intravenous fluids at the hospital, getting partial relief of symptoms. This individual received a USN Table 6 four hours later and experienced complete relief of symptoms.

After a dive to 50 fsw / 15 msw, a diver experienced visual disturbances and weakness in one arm and one leg. The diver made three additional dives, waited 54 hours before being treated with a USN Table 6 and experienced complete relief.

Two divers experienced difficulty walking after their dive, but they continued to dive. One of these individuals made four dives in two days to 80 fsw / 24 msw and experienced dizziness after the first dive. The diver received oxygen in the hospital and was treated with a USN Table 6 three hours after diving. The diver received three additional treatments and experienced complete relief of symptoms.

**NOTE: To date, there is no evidence that taking aspirin is beneficial in treating DCI, except to relieve pain.*

The second diver had made four dives in two days to depths of 120-165 fsw / 36.5-50 msw. Symptoms included difficulty walking and numbness in the leg after the second dive. The diver was treated with a USN Table 6 some 48 hours later and had relief of all symptoms.

Two divers had episodes of semiconsciousness but continued to dive. One diver was semiconscious after a dive to 112 fsw / 34 msw, but decided to make two more dives the next day to 69 fsw / 21 msw. Other symptoms included abdominal pain and dizziness. The diver received oxygen in the field and hospital, with partial relief of symptoms, was treated with a USN Table 6 three hours after the last dive and had complete relief. The second diver made four dives in two days to 112 fsw and experienced semiconsciousness and abdominal pain. The diver received oxygen and fluids in the field and hospital and was treated three hours later. Neurological symptoms persisted for two weeks.

Divers with previous injuries have more experience and hence are at an inherently higher risk because of repetitive exposure to the environment.

Table 4.10 *Number of Cases with a Previous Injury, Classified by Present Diagnosis*

	Classification of the Previous Injury					
Present Diagnosis	**Possible DCS**	**DCS**	**Pulmonary Barotrauma**	**AGE**	**None**	**TOTALS**
DCS-I	7	10	1	0	93	111
DCS-II	15	14	0	1	272	302
AGE	1	2	0	1	35	39
TOTALS	**23**	**26**	**1**	**2**	**400**	**452**

Previous Decompression Illness

Table 4.10 (above) shows data relating to divers who had experienced a previous incident of DCI. Table 4.11 (Page 52, top) shows data relating to the severity of symptoms. Similar to previous years, both show that of the 452 cases presented here a total of 52 divers (11.5 percent) had previously experienced either possible DCS (diver had symptoms but was never diagnosed with DCI nor treated in a hyperbaric chamber), actual DCS, pulmonary barotrauma or AGE. Divers with previous injuries have more experience and hence are at an inherently higher risk because of repetitive exposure to the environment (more dives, more total dives).

Divers who reported previous DCS (n=52) had logged more dives (median number 300) than those who had not reported such history (median 80 dives), and 15 of these divers reported having logged 1,000 or more dives. Only 17 of 52 divers (32.7 percent) with previous DCS had either rapid ascent, buoyancy or equipment

Table 4.11 *Number of Cases with a Previous Injury, Classified by Presenting Symptoms*

	Classification of the Previous Injury					
Previous Symptoms	Possible DCS	DCS	Pulmonary Barotrauma	AGE	None	TOTALS
Severe Neurological	3	5	0	1	86	95
Mild Neurological	19	19	1	1	244	284
Pain/Skin/ Nonspecific	1	2	0	0	70	73
TOTALS	**23**	**26**	**1**	**2**	**400**	**452**

problems or were not within table or computer limits — slightly lower than the 35.6 percent in the entire 1997 injury population. All divers with previous DCI followed a table or used a dive computer for the dive immediately preceding the onset of symptoms.

In more than a third of DCI cases, pain was the first symptom, while 81 percent of divers with DCI experienced pain at some point in their illness.

The second most common symptom was numbness and occurred in over 79 percent of DCI cases.

Summary

- Pain was the most common initial symptom occurring in 35 percent of all DCI cases. Eighty-one percent of divers with DCI experienced pain at some point in their illness.
- The second most common symptom was numbness, which occurred at some time in more than 79 percent of cases.
- Seven percent of all DCI cases had severe neurological symptoms (altered consciousness, paralysis, visual symptoms, bowel/bladder problems, gait abnormalities or convulsions).
- The traditional classification scheme (DCS I, DCS II, AGE) is frequently applied incorrectly by the reporting physicians. Fifty-six percent of 111 divers classified as DCS I reported neurological symptoms to DAN on the Diving Accident Reporting Form (DARF).
- The first symptoms developed within 30 minutes of surfacing in half of the cases. In 95 percent of these cases, DCI symptoms developed within 27 hours.
- Sixteen percent of divers with DCI reported having experienced symptoms before their last dive; 10 reported severe neurological symptoms, which supports the need for more education about the signs and symptoms of DCI.

Treatment – Section 5

In this chapter, several tables use the diagnosis of AGE, DCS I and DCS II provided by treating physicians. DAN has further classified DCS II by severe and mild. Definitions are as follows:

DCS II Severe — includes neurological symptoms of unconsciousness, semiconsciousness, paralysis, speech and visual disturbances, difficulty walking, bowel and bladder problems, and convulsions.

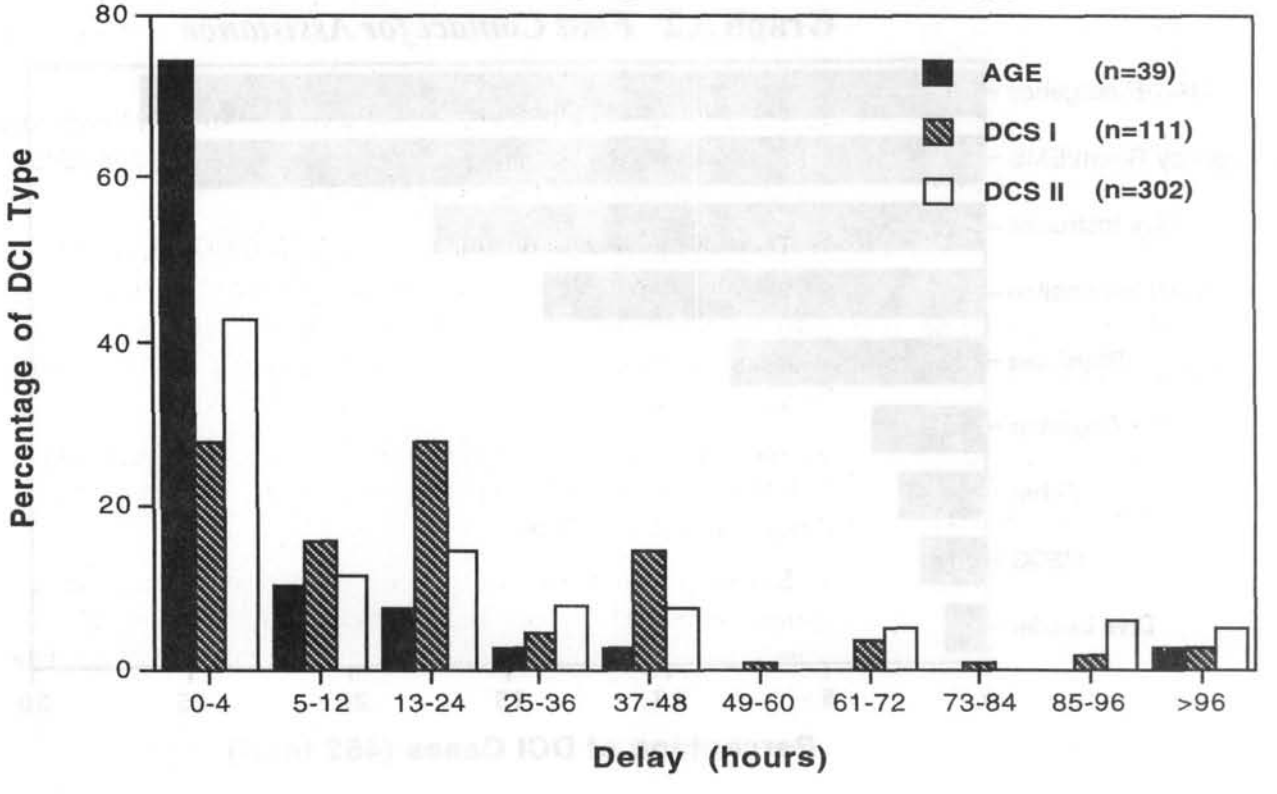
DCS II Mild — includes all other neurological symptoms (refer to Table 4.1, Page 45) for a list of all symptoms.

The ultimate outcome for divers experiencing decompression illness depends on early recognition of symptoms, prompt diagnosis and early institution of appropriate first aid and definitive treatment. The following data summarize the treatment information submitted to DAN in 1997 for the 452 reported cases of decompression illness.

Delaying the Call for Assistance

The data presented in Graph 5.1 are similar to those of previous years. Most calls for assistance within the first four hours were from divers who experienced more severe or recognizable symptoms. In the first four hours after symptom onset, 72 percent of AGE cases were reported, 48 percent of the DCS II cases and only 28 percent of the DCS I cases. In total, 41.5 percent of all DCI cases known to have been treated in DAN referral chambers worldwide were reported to DAN and are included in the report.

Graph 5.1 ***Delay From Symptoms Onset to Calling for Assistance***



The combined data indicate variable delays from the time symptoms are recognized to the time of calling for assistance. Twenty-nine percent of all DCI calls come between five and 24 hours after symptom onset, and 15 percent waited an additional day to call someone concerning symptoms. A further 13 percent waited more than 48 hours to place a call for assistance.

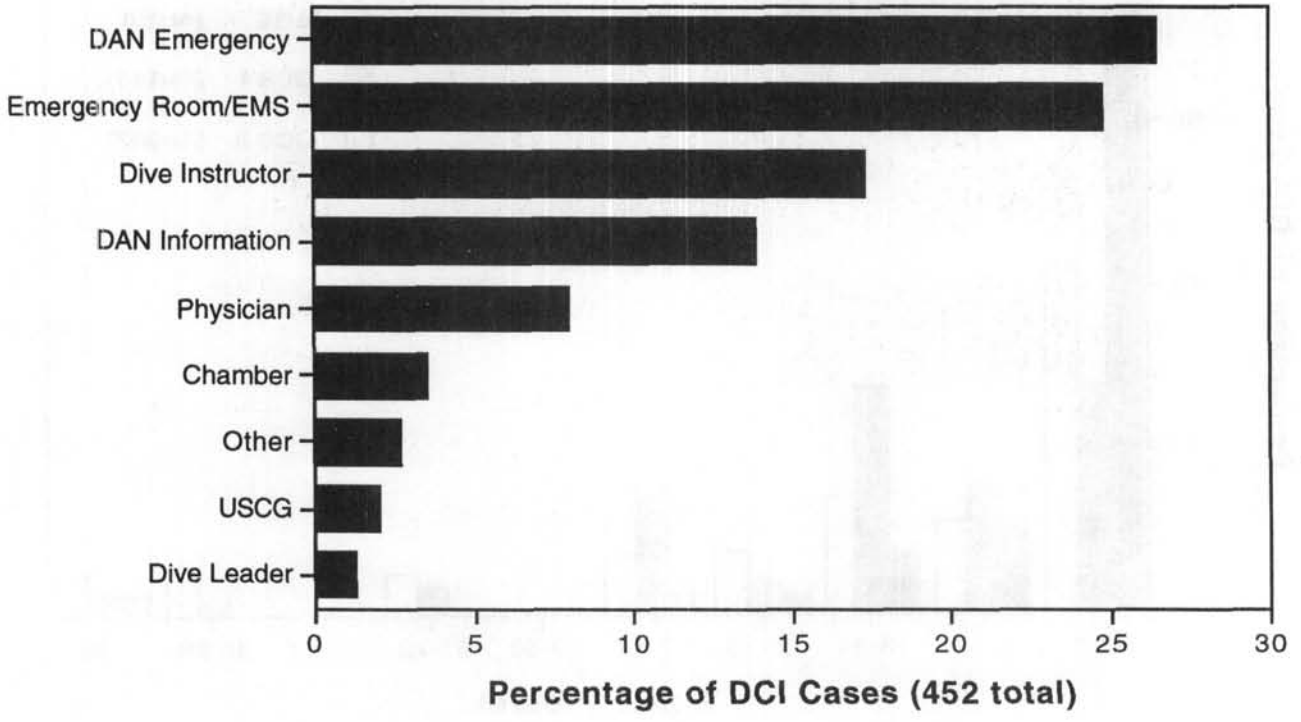
Forty percent of all DCI cases in the 1997 database initially contacted DAN.

DAN Medical Services continue to play an important role for divers experiencing symptoms of DCI. Forty percent of all DCI cases in the 1997 database initially contacted DAN through the Diving Emergency Hotline or through the Medical Information Line (Graph 5.2, below). An additional 36 percent of all cases first contacted a local physician, hospital emergency department, EMS or recompression facility for assistance and/or evaluation.

Nineteen percent of reported DCI cases initially sought advice from their dive instructors or dive guides. This underscores the importance of the need for dive instructors to be educated and trained in the recognition of the symptoms of DCI and appropriate first aid. These procedures include contacting DAN for referral to the closest appropriate physician and/or recompression facility.

Two percent of all reported cases of DCI received initial assistance from the U.S. Coast Guard, while the remaining 3 percent used the services of airport and hotel personnel, insurance companies, friends and the U.S. military. Contacts through EMS exceeded physician contacts in both 1997 and 1996. Also, 3.5 percent of the injury cases in 1997 first contacted a recompression facility directly.

Graph 5.2 ***First Contact for Assistance***



Initial Contacts to DAN

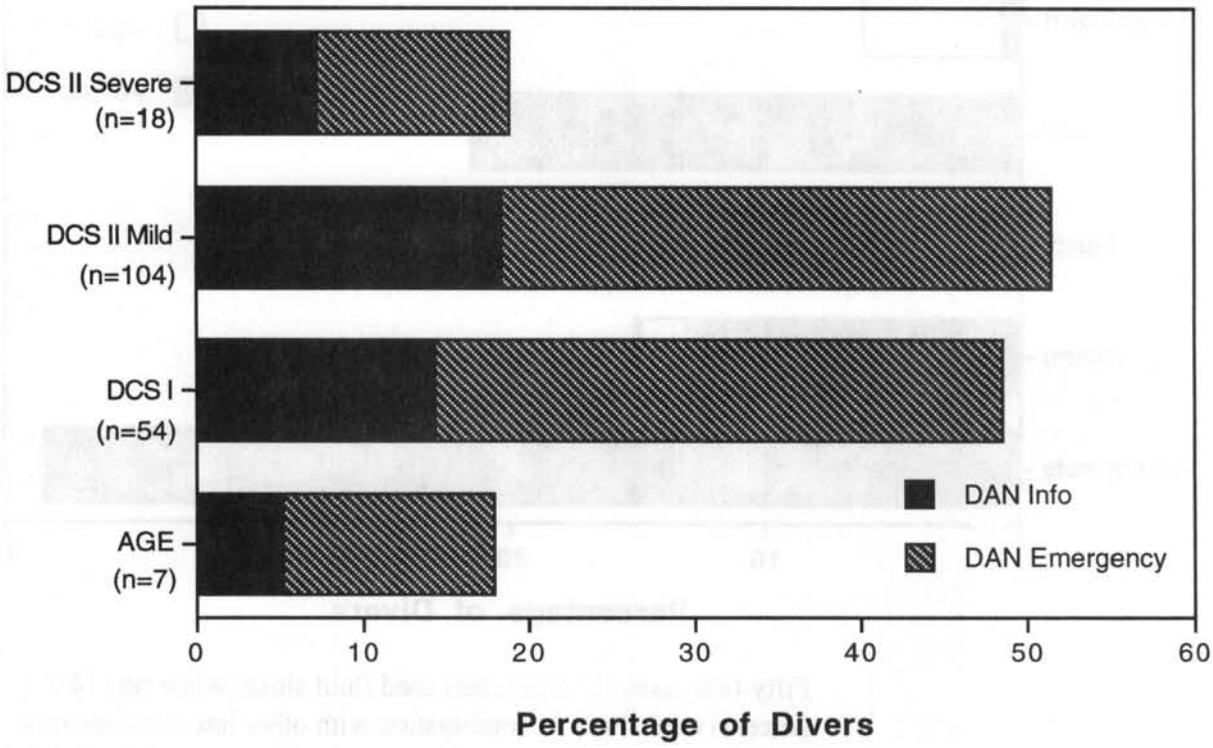
Of the 183 divers who utilized DAN as the initial contact, 176 did so for assistance with either DCS I (n=54) or DCS II (n=122). Graph 5.3 (below) shows the breakdown of these contacts, indicating whether they used the emergency or non-emergency telephone lines. The percentage of divers in 1997 who used the non-emergency information line for consultation on DCS II decreased slightly to 37 percent (n=45 out of 122 DCS II cases) when compared to 1996 data. Given the importance of prompt recognition and treatment of severe neurological DCS, this continues to be a disturbing statistic.

Only seven of the 39 (18 percent) divers who reported AGE cases in 1997 used DAN as the initial point of contact for assistance. Two cases were reported on the information line and five through DAN's Diving Emergency Hotline.

Very serious cases seem to have been easily recognized, with prompt contact to EMS. Callers to DAN were probably those who were more likely to have denied their symptoms or who were unsure if their symptoms were DCI-related.

Contacts through EMS exceeded physician contacts in both 1997 and 1996.

Graph 5.3 *DCI Type in Initial Calls to DAN*



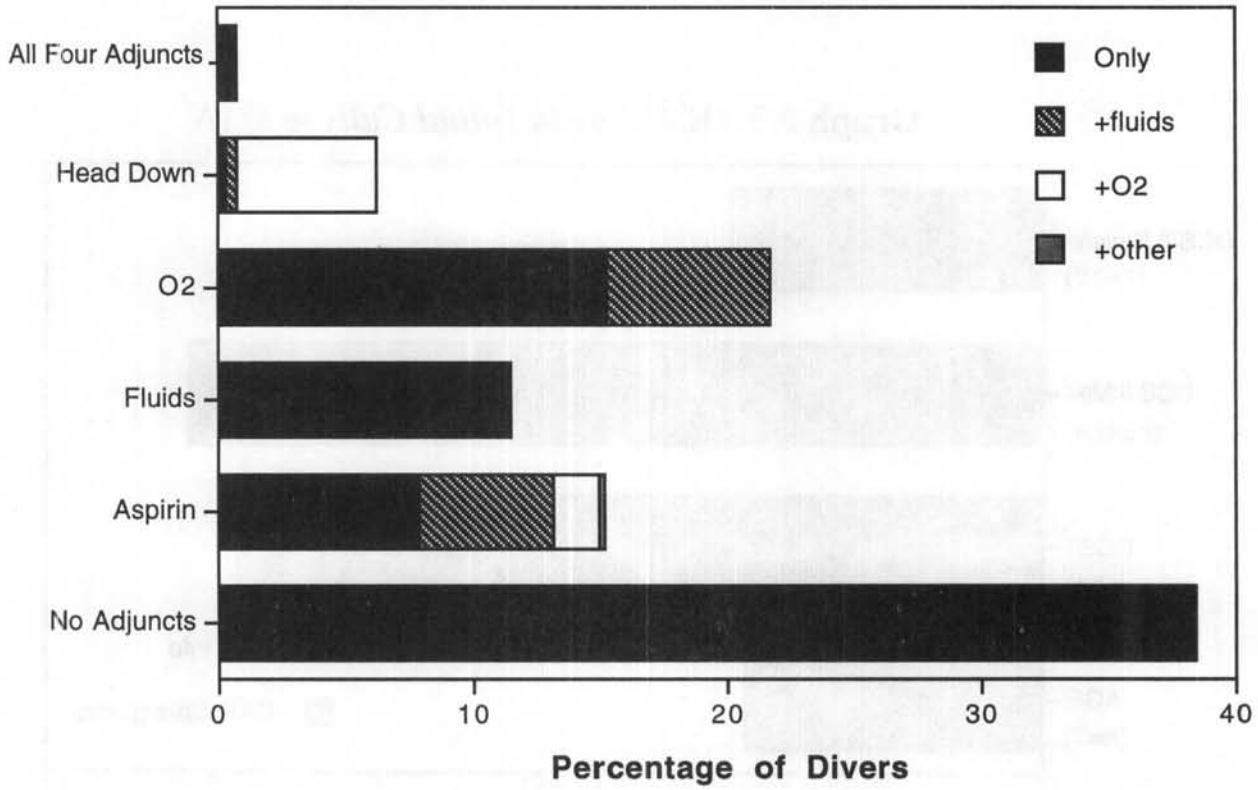
Of the 452 DCI cases, 59 percent used oxygen alone or in combination with other treatment modalities for first aid

Of the 32 other divers who were treated for AGE, the point of initial contact varied. Some (n=2) reported directly to a hospital emergency room, while some of the injuries prompted an initial contact with EMS (n=14); others reported their symptoms to their instructor (n=11). In two cases, the United States Coast Guard was the first point of contact, two divers contacted a local chamber, and one other diver called a local physician.

The Use of Oxygen First Aid and Other Adjuncts

Graph 5.4 (below) shows what first aid adjuncts (oxygen, oral fluids, head-down position or aspirin) were used by the 278 (61.5 percent) of the 452 DCI cases in this report. A total of 268 (59 percent) used oxygen alone or in combination with other treatment modalities for first aid (Graph 5.4, below). Sixty-nine cases (15.3 percent) used oxygen alone, while only 29 (6.4 percent) used fluid and emergency oxygen.

Graph 5.4 ***First Aid Used***



Fifty-two cases (11.5 percent) used fluid alone, while 66 (14.6 percent) used fluids in combination with other interventions (not including oxygen) as a first aid measure. Eight percent (n=36) used aspirin* alone, and 48 (10.6 percent) used aspirin in combination with some other therapy. Out of the reported DCI cases, none of the four treatments was used in 174 cases (38.5 percent).

**NOTE: To date, there is no evidence that taking aspirin is beneficial in treating DCI, except to relieve pain.*

Table 5.1 *Emergency Oxygen: 1995-1997*

Diagnosis	1997 (n=452)			1996 (n=483)			1995 (n=590)		
	N	O2 Use	%	N	O2 Use	%	N	O2 Use	%
AGE	39	33	84.6	58	52	90.0	46	38	82.6
DCS-I	111	63	56.8	122	60	49.2	161	67	41.6
DCS-II Severe	58	38	65.5	59	41	68.3	118	81	68.6
DCS-II Mild	244	134	54.9	244	156	64.2	265	141	53.2
TOTALS	**452**	**268**	**59.3**	**483**	**309**	**64.0**	**590**	**327**	**55.4**

Divers who experience post-dive DCI symptoms and receive complete or partial relief of symptoms after the use of oxygen may never enter the DAN database because they do not receive treatment at a recompression facility. DAN recommends that divers with symptoms be evaluated — even if they are symptom-free after oxygen.

Clinical and theoretical evidence supports the use of supplemental oxygen for first aid of DCI. The number of DAN oxygen providers has increased from 10,626 in 1996 to 12,396 in 1997.

The distribution of emergency oxygen use is listed in Table 5.1 (above). The efficacy of emergency oxygen use in conjunction with hyperbaric recompression therapy is discussed later and shown in Graphs 5.7 and 5.8 (Pages 59-60). Unfortunately, DAN does not have data on the duration of oxygen breathing, the type of delivery system used or the delay to starting oxygen after symptoms have begun. All three factors may be important in treating DCI and in the final outcome.

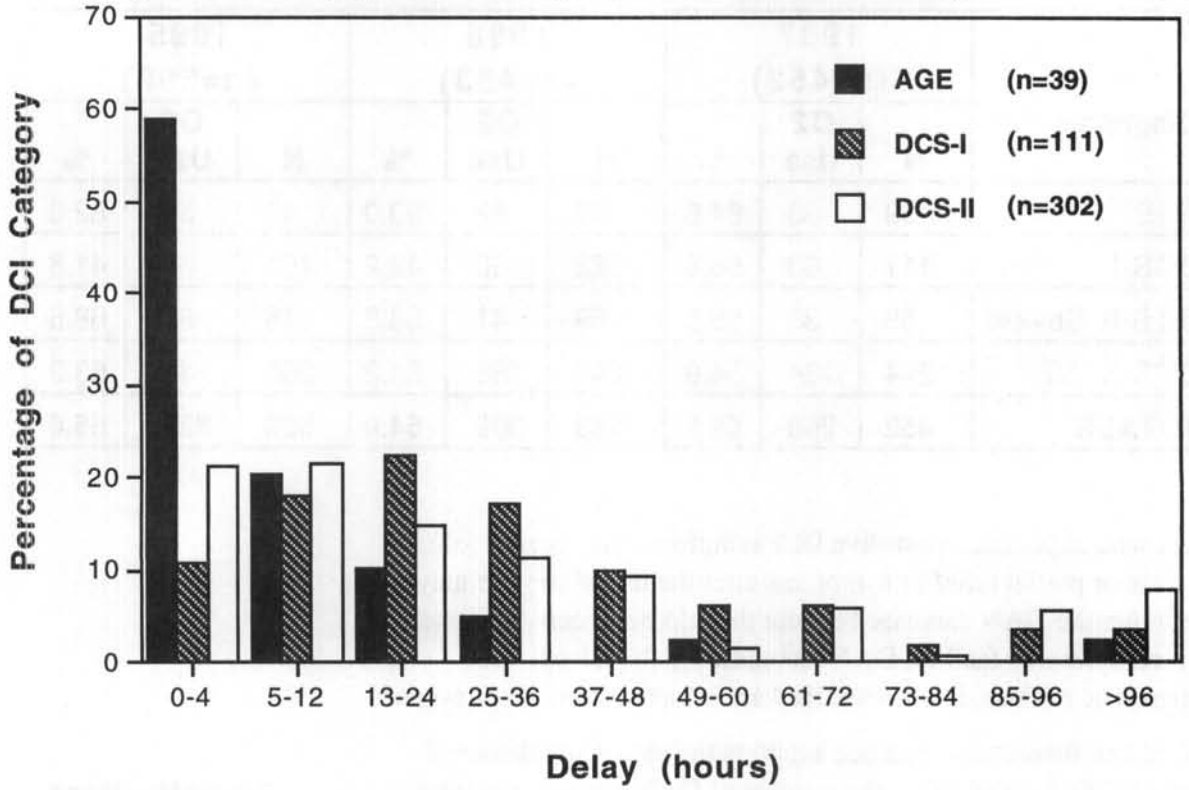
Delay to Recompression

Although significant variability from the time of symptom onset to the beginning of recompression therapy continues (see Graph 5.5, Page 58), 23 of the 39 cases of AGE (58.9 percent) received hyperbaric therapy within four hours of symptom onset, while 79 percent (n=31) were recompressed within 12 hours. Early treatment is crucial, and improved diver education in symptom recognition and emergency management may increase the percentage treated in less than 12 hours.

The delay in treatment for cases of DCS I and DCS II was similar to previous years' reports, with 10.8 percent and 21.2 percent respectively (12 of 111 DCS-I, and 64 of 302 DCS-II), being treated within four hours of symptom onset; and 28.8 percent and 42.7 percent (32 of 111 DCS I and 129 of 302 DCS-II) being treated within 12 hours.

Twenty-three of the 39 cases of AGE (58.9%) received hyperbaric therapy within four hours of symptom onset, while 79 percent (31) were recompressed within 12 hours.

Graph 5.5 ***Delay from First Symptom Onset to Recompression Therapy***



The reasons for delay in treatment may include:

- denial of symptoms by the injured diver;
- failure to recognize that signs and symptoms were due to DCI;
- use of remote dive locations requiring long intervals until evacuation;
- time passage as diver waits to see if symptoms spontaneously resolve;
- oxygen first aid relief followed by a return of symptoms.

Effectiveness of Recompression Treatments

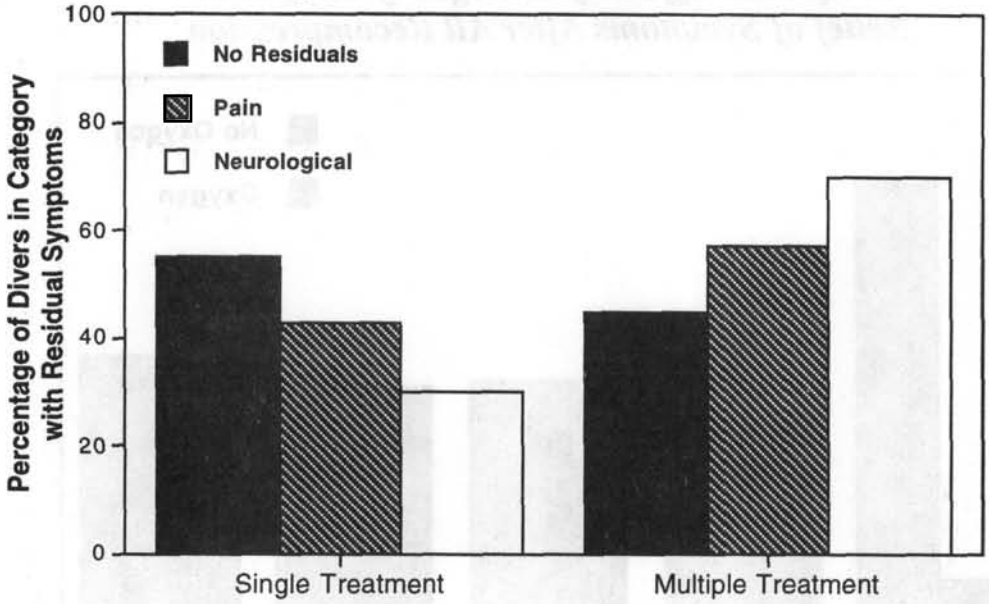
10.8 percent of divers with DCS-I and 21.2 percent of divers with DCS-II were treated within four hours of symptom onset.

Graph 5.6 (Page 59) shows diver outcomes after hyperbaric treatments for the 1997 DCI cases reported to DAN. More than half (69 percent) of all divers had resolution of all symptoms after hyperbaric treatment. Thirty-one percent (140 divers) of all cases reported had residual symptoms. Of these, 62 percent (87 divers) had residual neurological symptoms, while 38 percent (53 divers) had pain-only residual symptoms. These data are consistent with those reported in past years.

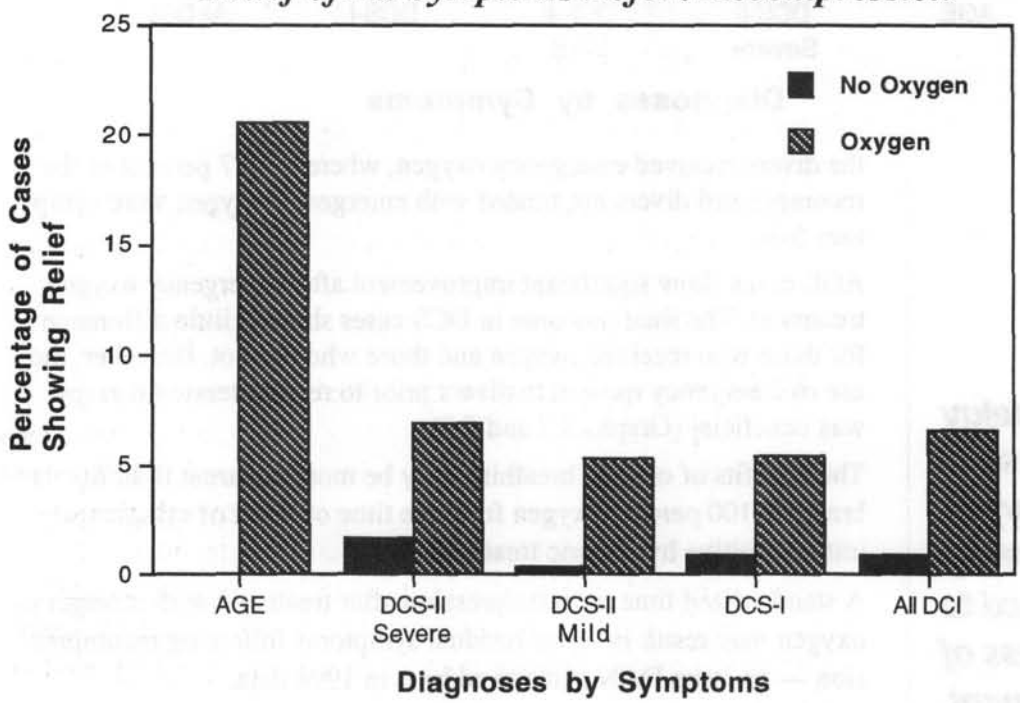
The cases are categorized into those divers who received one treatment, and divers who received multiple treatments. Factors that prevented complete resolution may be the delay to treatment and the initial severity of symptoms.

Graphs 5.7 and 5.8 (see Pages 59 and 60) show the improvement in overall symptom-free outcomes for those divers who receive emergency oxygen first aid.

Graph 5.6 ***Post-Treatment Residuals***

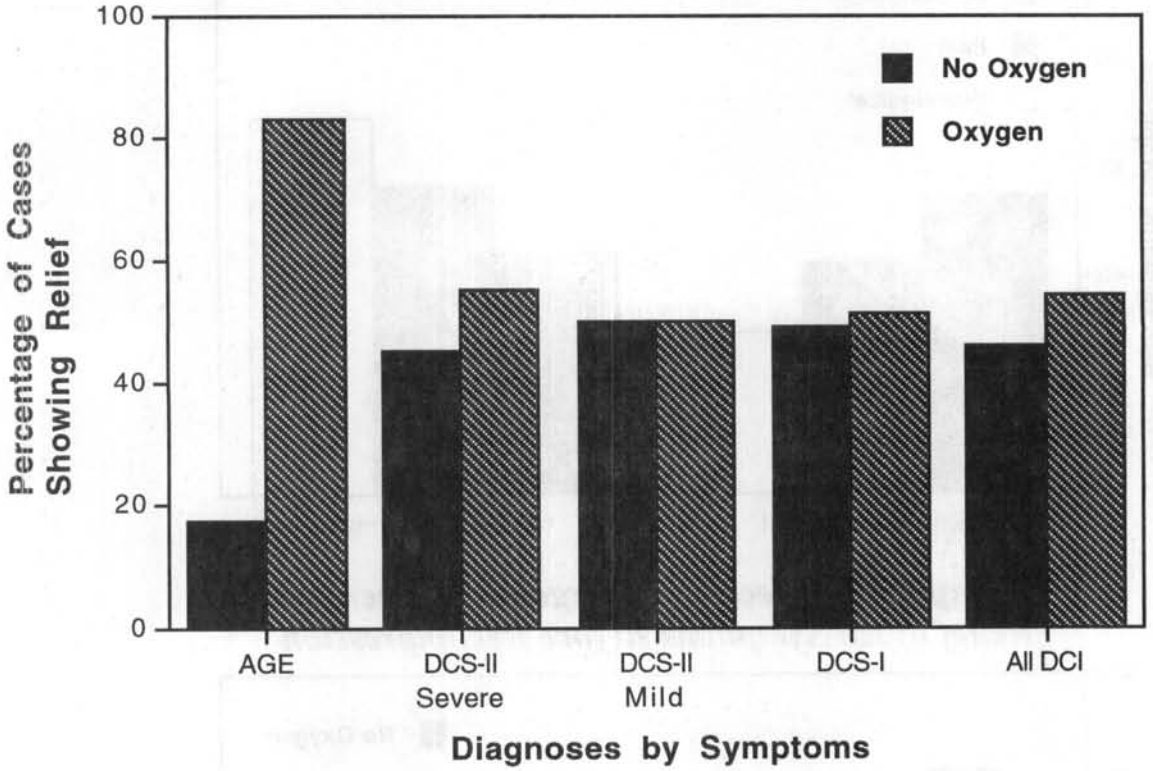


Graph 5.7 ***Effects of Emergency Oxygen in Relief of All Symptoms Before Recompression***



Eight percent of the reported DCI cases in 1997 were symptom-free after surface oxygen and before recompression therapy. In addition, almost 1 percent (0.9 percent) reported being symptom-free *without* oxygen before recompression. All divers received recompression therapy, even if they showed no symptoms when they arrived at the chamber. Sixty-nine percent (140 divers) of 312 cases had complete relief. Fifty-four percent of all DCI cases were symptom-free after all hyperbaric treatments (some received multiple treatments) when

Graph 5.8 ***Effect of Emergency Oxygen in Relief of Symptoms After All Recompression***



The effect of delay in the use of hyperbaric oxygen therapy is directly correlated to the success of the treatment.

the divers received emergency oxygen, whereas 45.7 percent of the recompressed divers not treated with emergency oxygen were symptom-free.

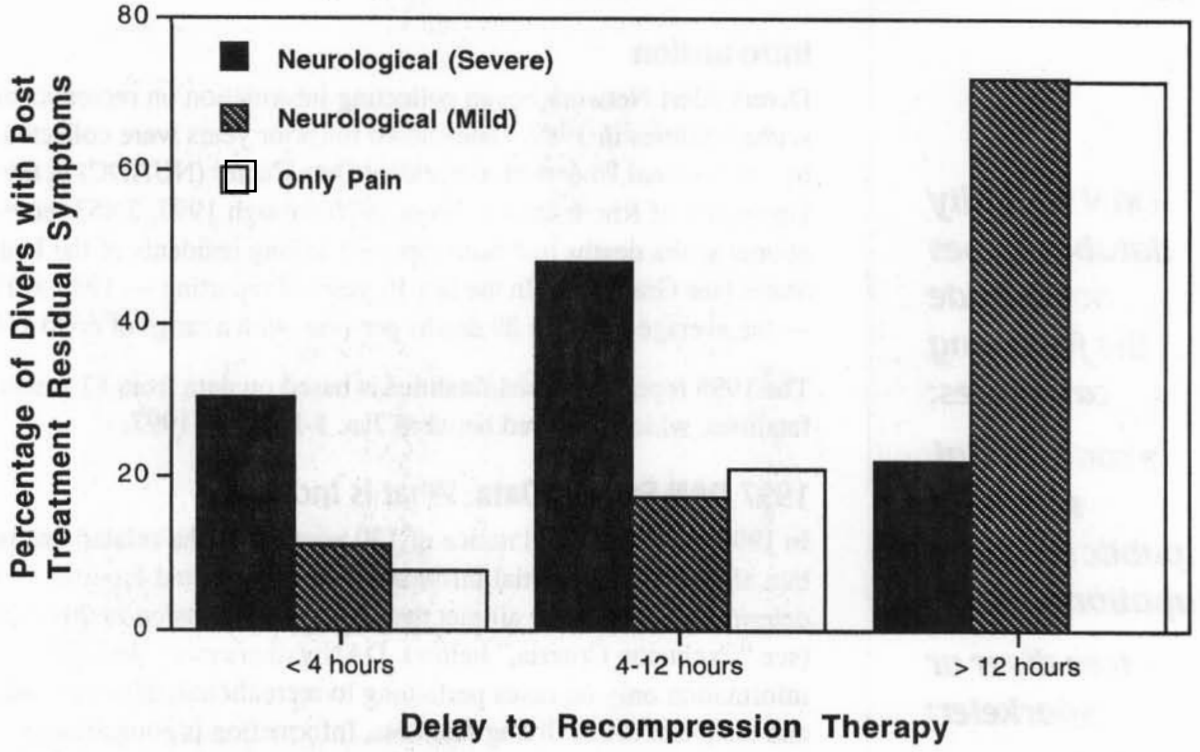
AGE cases show significant improvement after emergency oxygen treatment. The final outcome in DCS cases showed little difference for those who received oxygen and those who did not. However, the use of emergency oxygen in divers prior to recompression therapy was beneficial (Graphs 5.7 and 5.8).

The benefits of oxygen breathing may be more apparent if all divers breathed 100 percent oxygen from the time of onset of symptoms until definitive hyperbaric treatment.

A standardized time to recompression after treatment with emergency oxygen may result in fewer residual symptoms following recompression — an issue DAN plans to address in 1998 data.

A total of 140 cases (31 percent) had incomplete relief and were left with residual symptoms after recompression. The effect of delay in the use of hyperbaric oxygen (see Graph 5.9, Page 61) is directly correlated to the success of the treatment as measured by its ability to reduce or totally resolve the symptoms. Increasing delays result in incomplete resolution of symptoms for all types and severity of DCI. The percent of divers with post-recompression residual symptoms continues to decrease, which is likely due in part to early symptom recognition and emergency oxygen first aid.

Graph 5.9 ***Percentage of Divers with Post-Recompression Residual Symptoms Related to Delay to Recompression Therapy***



Summary

■ Symptom recognition and emergency first aid for suspected DCI are important in the ultimate resolution of decompression illness. Delays due to confusing symptoms, symptom denial by the diver and remote dive locations contribute to the presence of residual symptoms after recompression therapy.

■ The greater recognition of symptoms of AGE, perhaps due to their severity and acute nature, results in more prompt treatment.

■ Education in the recognition of decompression illness may improve the response time to provide emergency oxygen first aid and appropriate recompression treatment. Education of divers and instructors in the recognition of symptoms of DCI is critical. The rising percentage of divers initially contacting dive instructors supports the need for education and awareness by this group.

■ Fifty-nine percent of all reported DCI cases received emergency oxygen first aid. An increasing number of divers stop the use of oxygen without receiving medical evaluation. In many instances, these same divers report to a hyperbaric facility at a later time and on examination are found to have significant signs or symptoms.

■ Delay in recompression therapy is associated with a significantly greater probability of residual symptoms for most types of DCI.

Symptom recognition and emergency first aid of suspected DCI are important in its ultimate resolution.

Scuba Fatalities – Section 6

Introduction

Divers Alert Network began collecting information on recreational scuba fatalities in 1989. Data shown for prior years were collected by the National Underwater Accident Data Center (NUADC) at the University of Rhode Island. From 1970 through 1997, 2,853 recreational scuba deaths had been reported among residents of the United States (see Graph 6.1). In the last 10 years of reporting — 1988 to 1997 — the average has been 89 deaths per year, with a range of 66 to 114.

The 1998 report on scuba fatalities is based on data from 82 scuba fatalities, which occurred between Jan. 1-Dec. 31, 1997.

DAN's fatality database does not include the following categories:

- ***commercial, scientific, public safety or occupational diver;***
- ***free diver or snorkeler;***
- ***foreign national not diving in U.S. waters;***
- ***non-diving-related accident, such as a boating accident.***

1997 DAN Fatality Data: What Is Included

In 1997, DAN received notice of 130 possible scuba-related deaths, but, after collecting initial information on all reported fatalities, were determined *not* to have all met the criteria for inclusion in this report (see "Exclusion Criteria," below). DAN gathers more detailed information only on cases pertaining to recreational, personal-task and technical scuba diving fatalities. Information is compiled on those fatalities involving U.S. residents worldwide and foreign nationals in U.S. waters. Uncertified divers who attempt scuba for recreational purposes are also included.

Exclusion Criteria

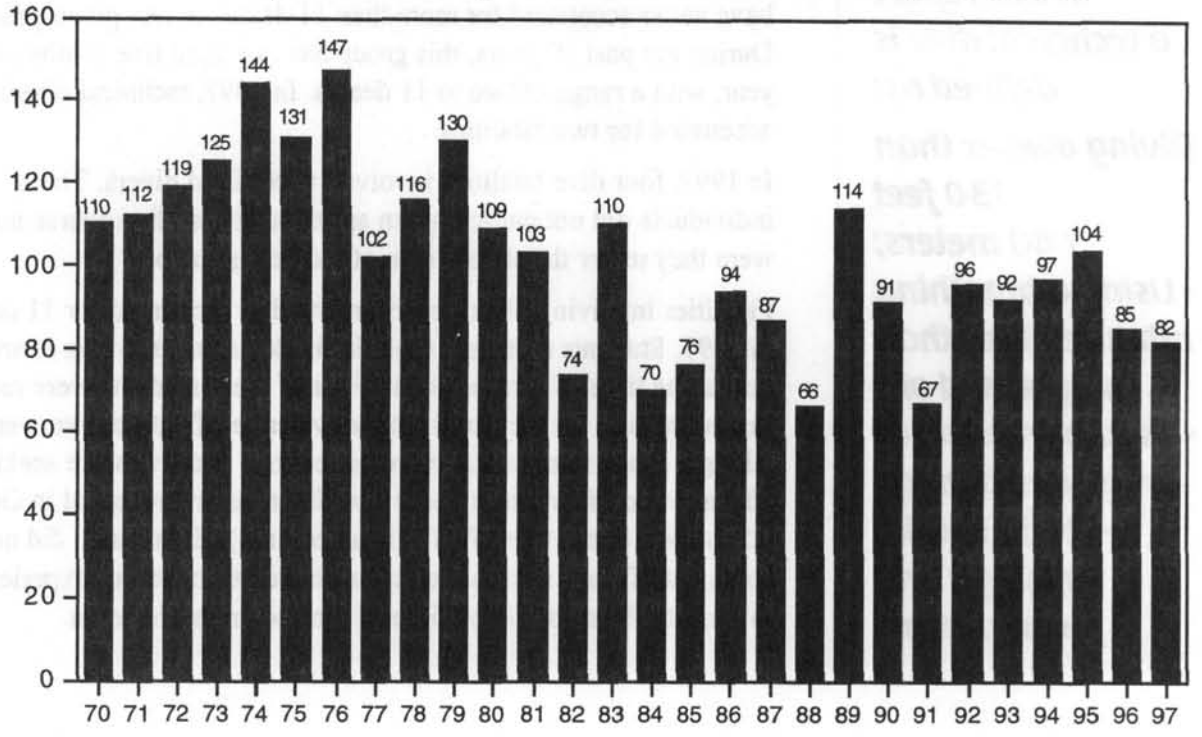
The DAN fatality database does not include any fatality which falls into the following categories:

- commercial, scientific, public safety or occupational diver;
- free diver or snorkeler;
- foreign national not diving in U.S. waters; and
- non-diving-related accident, such as a boating accident.

Of the 130 deaths reported in 1997, 48 were excluded: 16 were free divers; 14 were commercial or occupational divers; 10 were foreign nationals not diving in U.S. waters; five were not diving-related; and three were public safety divers.

Since the number of active divers and number of dives in any given year is unknown, it is not possible to determine with any degree of certainty the mortality rate among recreational scuba divers.

Graph 6.1 *Yearly U.S. Recreational Diving Fatalities*



Breakdown of Fatalities: Year, Certification, Type of Dive

Graph 6.2 (Page 64) gives a breakdown of recreational scuba deaths, derived from information about each case. Deaths among certified divers who reportedly dived within the limits of their certification and experience accounted for 59 deaths in 1997.

The number of certified recreational divers who were attempting to make a dive they were not qualified to make ranged between three and 15, with an average of nine deaths per year. Based on certification level and advanced training information contained in the reports sent to DAN, these individuals were performing dives requiring special training and equipment they did not possess. The largest number of these deaths involved attempts at deep diving, wreck penetration or cave diving. In 1997, this group represented three fatalities and are classified as "Recreational/Technical Divers" on Graph 6.2 (Page 64).

In this report, a technical dive is defined as one in which one of the following conditions existed:

- Dive deeper than 130 feet / 40 meters;
- Use of a breathing mixture other than compressed air;
- Decompression or overhead diving (in shipwrecks, caves or under ice); and
- Use of special training and equipment.

These levels of exposure exceed established recreational guidelines.

Deaths among divers who reportedly dived within the limits of their certification and experience accounted for 59 deaths in 1997.

In this report a technical dive is defined as:

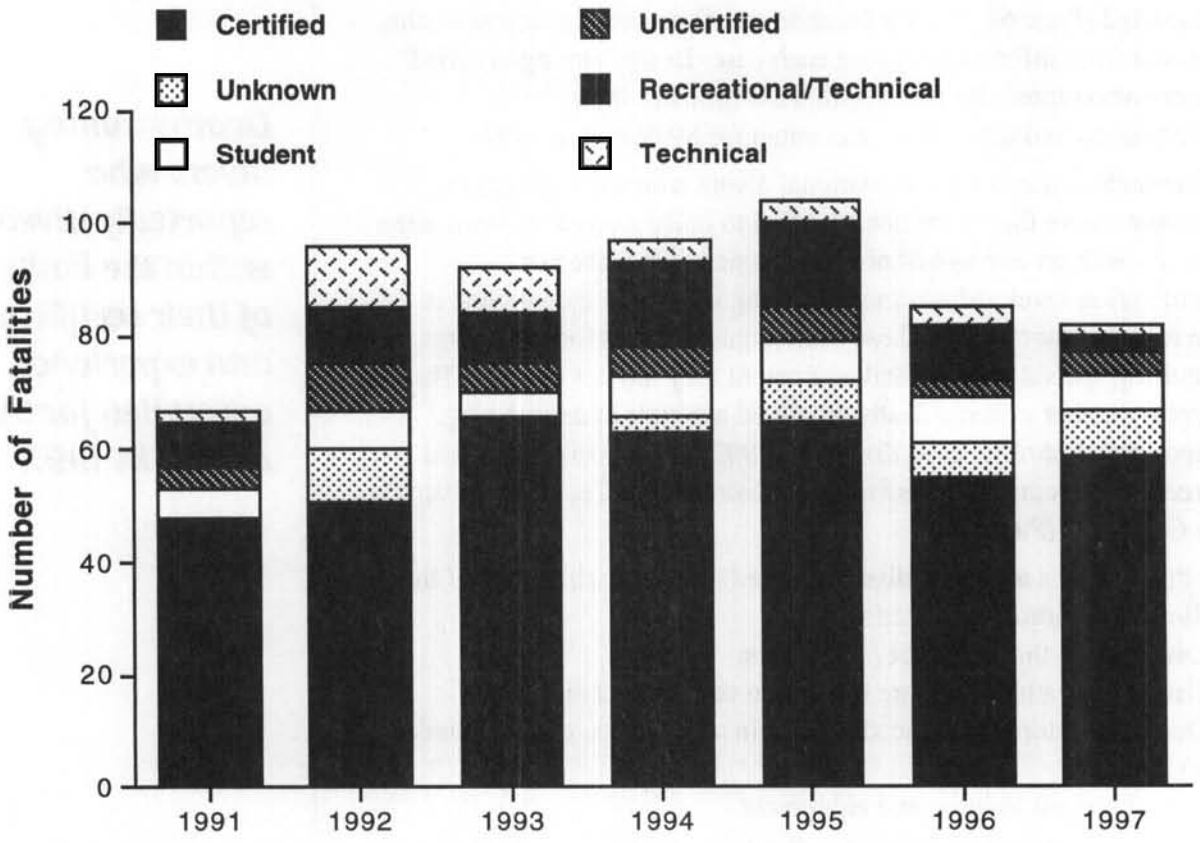
- ***Diving deeper than 130 feet / 40 meters;***
- ***Using a breathing mixture other than compressed air;***
- ***Decompression or overhead diving;***
- ***Using special training and equipment.***

Deaths among divers who have received specialized training have never accounted for more than 11 deaths in any given year. During the past 10 years, this group has averaged five deaths per year, with a range of two to 11 deaths. In 1997, technical divers accounted for two fatalities.

In 1997, four dive fatalities involved uncertified divers. These individuals did not participate in an instructional dive course nor were they under the supervision of a dive instructor.

Fatalities involving divers under instruction accounted for 11 deaths in 1997. Students represent those individuals under diving instruction at the time of their accident. Four of these students were receiving instruction for their initial open-water certification; two were taking a scuba familiarization resort course; and five were seeking advanced certifications. (These five divers are represented in Graph 6.2, below, in the "Certified" divers column). Eight cases did not contain sufficient information regarding certification of experience to classify them for Graph 6.2 and are shown as unknown.

Graph 6.2 ***Breakdown of Scuba Fatalities***



Preliminary Report on 1998 Recreational Fatalities

This page is a brief introduction to scuba fatalities in 1998, which will be presented in detail in the next (year 2000) report.

As of October 21, 1998, 66 fatalities had been reported to DAN for the reporting year 1998. Of these 68 cases, 31 divers were verified as certified recreational divers, four were students participating in initial training (i.e., an open-water certification or a scuba familiarization course), nine were technical divers, and two were conducting personal tasks.

Among the nine technical divers, two were students under technical training, which entailed the use of mixed gases while diving, and diving to depths exceeding 130 feet / 40 meters. In the year 2000 edition of this report, mixed-gas technical diver fatalities will be placed in an appendix, as the DCI injury cases are at present.

There was also one known uncertified diver. Nineteen cases waiting further investigation lack sufficient information to determine certification and experience. Of the 66 fatalities reported in 1998, 14 (21.5 percent) involved women. These are preliminary numbers and will likely change when end-of-year data are added.

More than half the 1998 fatalities (65.2 percent) occurred between May and September: May (nine), June (four), July (nine), August (14) and September (seven). The nine fatalities reported in May 1998 were higher than the fatalities reported in May 1997 (four). The fatalities in summer months (May-September) usually range from four to 14 deaths per month.

Florida had the highest number of reported deaths in 1998: 17 deaths had been reported as of this writing. California reported eight deaths; New Jersey had three deaths in 1998; Hawaii, Virginia, New York, Massachusetts, Washington and Oregon each had two reported deaths. Fifteen diving-related deaths occurred outside the United States.

More than half of the 1998 fatalities (65.2 percent) reported thus far occurred between May and September.

Methods of Fatality Data Collections – Section 7

In 1997, about 34 percent of the fatality reports came to DAN via telephone calls.

In general, case collection begins with a single telephone call or a newspaper clipping, in which the characteristics of individuals who share a common outcome are described. Unfortunately, in this series, the outcome is death, and all the victims died while scuba diving or shortly after diving. Obviously, since death is not the expected outcome of a scuba dive, the detailed study of the cases reported should provide some insight into the causes of these fatalities. Dives that have fatal outcomes may pose different risks for divers than dives that do not result in a fatality.

How Information Is Collected – Initial Contacts

Table 7.1 (below) shows the agencies and services that supply DAN with initial information regarding scuba-diving fatalities. Most reports come from subscription services, which include news clipping services (such as Luce and Burrelle) and computer electronic mail services (such as CompuServe). In 1997, about 34 percent of the fatality reports came to DAN via telephone calls through the DAN network, which includes calls on DAN's Medical Information Line and the Diving Emergency Hotline and Internet listings. Medical examiners, coroners, investigative agencies, hyperbaric chamber personnel and dive agencies may also contact DAN's staff regarding a diving fatality.

Table 7.1 *Initial Contacts*

	Inside United States	Outside United States	Total	Percent
DAN Network	17	11	28	34.1
Subscription Services	19	1	20	24.4
Investigative*	10	0	10	12.2
Lifeguard/Chamber	6	2	8	9.8
Medical Examiner/Coroner	4	1	5	6.1
Family/Friend	2	3	5	6.1
E-mail / Correspondence	2	2	4	4.9
Newspaper Direct	2	0	2	2.4
Total	**62**	**20**	**82**	**100.0**

* *Police, Sheriff, Marine Patrol and USCG*

The investigative agencies — including sheriff and police departments, U.S. Coast Guard and other reporting agencies, and medical examiners/coroners — who provide fatality reports to DAN receive bimonthly mailings of *Alert Diver* and a complimentary copy of this report.

Since scuba fatalities are relatively rare, many agencies who follow up on the fatality investigations are unfamiliar with scuba diving. DAN offers investigators and medical examiners protocols for investigations and autopsies; it also provides access to DAN physicians who are knowledgeable in diving fatalities and forensic pathology. DAN assists investigation agencies, but is not an investigative agency itself.

DAN assists investigation agencies, but it is not an investigative agency itself.

Table 7.2 ***Primary Sources of Information***

Primary Source	Total	Percent
Autopsy and Investigative Report	29	35.4
Family/Friend Only	8	9.8
Autopsy Only	7	8.5
Coroner's Summary Only	7	8.5
Coroner's Summary and Investigative Report	5	6.1
Local Contact Only	5	6.1
Autopsy and Family/Friend	4	4.9
Investigative Report Only	4	4.9
Newspaper	3	3.7
Medical Examiner and Chamber	3	3.7
Autopsy, Investigative Report, and Family/Friend	2	2.4
Autopsy and Witness	1	1.2
Coroner Summary and Family/Friend	1	1.2
Medical Examiner, Investigative Report, and Witness	1	1.2
Witness Only	1	1.2
Unknown	1	1.2
TOTAL	**82**	**100.0**

Collecting Information After Initial Contact

Table 7.2 (above) lists the primary sources of information used in the analysis of scuba fatalities. Information about diving fatalities, no matter how it is received, constitutes a starting point for collecting more information.

DAN first verifies a reported fatality by contacting local authorities, and then obtains information on fatalities from autopsy or coroner reports and reports from investigative agencies (e.g., sheriff, police,

reports and reports from investigative agencies (e.g., sheriff, police, USCG, Marine Patrol or lifeguard services). In 71.9 percent of the cases reported in 1997, DAN received autopsy or coroners' reports and investigative reports.

If possible, DAN gathers statements from persons involved with, or witnesses to, the dive event. This may include dive buddies, other divers or rescue dive personnel. In some cases, to get information regarding a diver's medical history and dive experience, DAN may contact the decedent's family.

Diving fatalities fall under the jurisdiction of the local medical examiner, who often performs forensic autopsies in order to determine the cause of death.

In 1997, of 82 fatalities, a body was recovered in 77 incidents, and autopsies were performed in 66 of these cases.

Diving fatalities fall under the jurisdiction of the local medical examiner: frequently, these officials perform forensic autopsies in order to fully determine the cause of death. In 1997, of 82 fatalities, a body was recovered in 77 incidents, and autopsies were performed in 66 of these cases; no autopsy was performed in four cases; and in seven cases DAN did not have enough information to determine if an autopsy was performed. Some states do not request an autopsy on every accidental death, or the medical examiner may decide that an autopsy is unnecessary. An autopsy report was available in 56 of the 66 cases (85 percent).

DAN's medical staff has increased its efforts to collect this information, and cooperation between investigative agencies and medical examiners has increased. DAN now receives more autopsy and investigative reports for analysis. Often sufficient information is available to review dive fatalities, but an autopsy report makes it possible for DAN's medical personnel to define contributing medical conditions and individual behaviors that may contribute to scuba fatalities.

Unfortunately, due to the absence of non-investigative data — most notably, health history — all cases lack some information. Medical history is rarely obtained, even in cases where an autopsy is performed. Local or state regulations, litigation, family request or the remoteness of foreign locations can also restrict information. All cases are counted, however, unless they fall into one of the exclusion categories listed on Page 62.

Locations of Scuba Fatalities

Tables 7.3 and 7.4 (Pages 69 and 70) show the location of scuba fatalities by state (within the United States) or by non-U.S. locations. Since the total number of dives in each locale is not known, no conclusion can be drawn concerning the relative safety or risk of any of the listed dive locations. Typically, deaths occur at a variety of dive sites and under various conditions. The number of deaths in Florida and California represents approximately one-third (38 percent) of all scuba fatalities in the United States. These deaths occurred at many different dive sites throughout the two states.

Table 7.3 *Location of Diving Fatalities by State*

	Certified	Uncertified	Unknown	Total	Percent
Florida	18	1	0	19	23.2
California	5	1	2	8	9.9
Hawaii	2	1	1	4	4.9
New Jersey	4	0	0	4	4.9
Texas	4	0	0	4	4.9
North Carolina	3	0	0	3	3.7
Washington	3	0	0	3	3.7
Massachusetts	1	1	0	2	2.4
New York	2	0	0	2	2.4
Wisconsin	2	0	0	2	2.4
Alabama	1	0	0	1	1.2
Arizona	1	0	0	1	1.2
Maine	1	0	0	1	1.2
Michigan	1	0	0	1	1.2
Mississippi	0	1	0	1	1.2
Montana	0	1	0	1	1.2
Ohio	1	0	0	1	1.2
Pennsylvania	1	0	0	1	1.2
South Carolina	1	0	0	1	1.2
Utah	1	0	0	1	1.2
Virginia	1	0	0	1	1.2
Total	**53**	**6**	**3**	**62**	**75.6**

Florida and California have always led in the number of reported scuba fatalities. This is due in part to large state populations and a large coastline, popular with residents and tourists. In 1997, Florida, California, and Hawaii accounted for 38 percent of all reported U.S. fatalities in the United States.

The U.S. coastline popular between Maine and New Jersey is another area popular with scuba divers. This area has many deep dives and wreck dives. The nine fatalities in this area represent 10.9 percent of U.S. fatalities. This same area also accounted for 10.4 percent of the fatalities reported in 1996.

Due to large state populations and large, popular coastlines, Florida and California lead in the number of reported scuba fatalities each year.

Table 7.4 *Location of Diving Fatalities Outside the United States*

Country	Certified	Uncertified	Unknown	Total	Percent
Mexico	5	0	2	7	8.5
Bonaire	2	0	2	4	4.9
Bahamas	1	1	0	2	2.5
British Virgin Islands	1	0	1	2	2.5
Belize	1	0	0	1	1.2
Puerto Rico	1	0	0	1	1.2
Solomon Islands	1	0	0	1	1.2
Turks & Caicos	1	0	0	1	1.2
U.S. Virgin Islands	1	0	0	1	1.2
Total	**14**	**1**	**5**	**20**	**24.4**

The number of U.S. citizens who died while scuba diving abroad represented 24.2 percent of all fatalities reported on in 1997.

Based on reports to DAN, the number of U.S. citizens who died while scuba diving abroad represented 24.2 percent of all fatalities that met the inclusion criteria in 1997. The percentage continues to increase, up from 21.2 percent of the 1996 fatalities.

DAN makes every effort to track and record fatalities of U.S. residents, no matter where in the world they occurred. If a geographical area is not listed in Table 7.4, DAN recorded no fatalities in that area.

To report an injury, a fatality or a near-miss in diving, call DAN's Medical Department at +1-919-684-2948 or 800-446 2671.

Divers Alert Network
The Peter B. Bennett Center
6 West Colony Place
Durham, NC 27705

Fatality Dive Profile – Section 8

Primary Dive Activities

Table 8.1 (below) shows the primary dive activity of the 82 divers who died in 1997. The most common diving activity listed on fatality reports was "pleasure / sightseeing," and diving fatalities that occurred while divers were under instruction continued to be all too common. "Under instruction" includes participants in scuba familiarization courses, initial diving certification and advanced diving certification classes.

Of the 11 fatalities that involved divers under instruction, four occurred during initial open-water certification, two involved persons registered in a scuba familiarization class, and five took place while the divers were under instruction to learn advanced skills. Those divers who were in an initial certification or scuba familiarization course are included in the "uncertified" category. Four divers had no record of any formal dive training, and the level of training, if any, in eight other fatalities was not known.

Most divers engage in diving activities that are compatible with their level of training and experience, but, unfortunately, small numbers of individuals attempt to stretch the limits of their diving skills: these divers often engage in specialty type dives (e.g., caves, wrecks, deep diving) without proper training or experience. Each year a small but significant number of people die without proper equipment or when using diving equipment without formal training.

More than half of all fatalities occur to divers making dives for sightseeing or for pleasure.

Table 8.1 *Primary Dive Activity*

Dive Activity	Certified	Uncertified	Unknown	Total	Percent
Pleasure/Sightseeing	35	2	7	44	53.7
Spearfishing/Hunting	10	1	1	12	14.6
Under Instruction	5	6	0	11	13.4
Wreck (no penetration)	5	0	0	5	6.1
Deep (> 130 feet)*	3	0	0	3	3.7
Night	3	0	0	3	3.7
Cave*	1	0	0	1	1.2
Photography	1	0	0	1	1.2
Working	0	1	0	1	1.2
Wreck (penetration)*	1	0	0	1	1.2
TOTALS	**64**	**10**	**8**	**82**	**100.0**

** Technical dives*

Sightseeing and Instruction

Most people scuba dive for sightseeing or pleasure, so it is not surprising that the greatest number of fatalities occurs under these circumstances. More than half (53.7 percent) of all fatalities that occurred in 1997 involved divers whose primary diving activity was "pleasure / sightseeing." As indicated above, 11 fatalities (13.4 percent) occurred in situations where the divers were under instruction.

In 1997, five deaths occurred while the diver was performing a technical dive.

Working Dives, Spearfishing & Underwater Photography

Seventeen percent of the 1997 fatalities involved divers who were performing working dives, spearfishing or engaging in underwater photography. This is an increase over the 10 percent reported in 1996. A "working dive," for the purpose of DAN's database, is a dive in which scuba equipment is used to accomplish a specific dive-related or personal task. The working divers in the DAN fatality database include individuals who were attempting to perform boat repairs, salvage lost personal gear or free a fouled anchor line. Divers should take extra caution when performing tasks that may divert their attention from exercising fundamental safe-diving techniques.
Note: Military and commercial diving fatalities are not included in DAN's database.

Technical Dives

There is no universally accepted definition of what constitutes a technical dive or, for that matter, a technical diver. For the purposes of DAN's accident and fatality database, a technical dive is defined as one in which any of the following conditions existed:

- Diving deeper than 130 feet / 40 meters;
- Use of a breathing mixture other than compressed air;
- Decompression or overhead diving (in shipwrecks, caves or under ice);
- Use of special training and equipment such as rebreathers.

As more divers look beyond traditional recreational scuba diving and employ newer and more advanced technology, it is logical to assume that divers using non-traditional gas mixes and equipment will make up a greater number of the fatalities. For the purpose of this report, DAN has placed extraordinarily deep dives, wreck penetration dives, and cave dives in the category of technical dives. Because use of enriched-air nitrox (EAN) has become so commonplace in the recreational diving community, DAN will likely change the criteria used for classifying a dive as a technical dive when evaluating 1998 fatalities.

Five deaths occurred in 1997 while the diver was performing a technical dive. Two of these six fatalities involved divers who had specialized training and certification, and who used specialized equipment to perform the dives. Most of these fatalities involved individuals who were ill-prepared, or lacked specialized training, certification or equipment for the "Recreational / Technical" category.

Cave diving deaths continued to decrease: nine occurred in 1995; five in 1996; and one in 1997. A technical (or specialty) dive should never be attempted without proper equipment, including redundant, emergency backup systems and safety devices.

A technical or specialty dive should never be undertaken without proper equipment.

Table 8.2 *Percentage of Dive Platform Use*

Entry	1997	1996	93-95	90-92
Shore	37.8	40.0	37.3	45.5
Charter Boat	36.5	38.8	33.0	28.5
Private Boat	22.0	18.8	27.7	23.8
Pool	0.0	0.0	1.0	0.8
Unknown	3.7	2.4	1.0	1.4
Total	**100.0**	**100.0**	**100.0**	**100.0**

Dive Entries – Shore, Boat, Pool

Table 8.2 shows the type of dive platforms used by divers involved in a fatal diving incident. In most years for which DAN has data, a shore entry was used in nearly half of the dives which had a fatal outcome. In 1997, charter- or private-boat diving made up a total of 58.5 percent of all scuba fatalities, a figure very similar to the 57.6 percent in 1996. As in 1996, no 1997 fatalities involved a diver using scuba gear in a swimming pool.

Divers in Groups When Fatal Mishaps Occurred

Table 8.3 shows the number of divers reported to be in the dive group at the time of the fatality. As in previous years, the greatest number of fatalities occurred during dives with two divers in the group.

Twelve percent of the 1997 diving fatalities involved divers entering the water without a buddy.

This is an increase from the 8.2 percent reported in 1996.

Twelve percent of the 1997 fatalities involved divers diving without a buddy —an increase from the 8.2 percent reported in 1996. A few fatalities occurred while the diver was with a large group but not diving with a designated buddy. Since every dive training organization emphasizes the need to dive with a buddy, all of these solo divers made what must be considered a violation of accepted safe-diving procedures.

In DAN's database, buddy separation is reported in nearly two-thirds (60.7 percent) of the fatalities reported each year.
While diving with a buddy may range from keeping close contact throughout the dive, to being in the same general area, having another diver available to offer assistance may mean the difference between life and death. Buddy separation eliminates the availability of immediate assistance and significantly increases the chance that a diver in distress will drown before reaching the surface.

Buddy separation eliminates the availability of immediate assistance.

Table 8.3 *1997 - Number of Divers in a Group*

Number in Dive Party	1997	1996	93-95
1	12.2	8.2	9.0
2	28.0	21.2	22.6
3	11.0	12.9	14.9
4	8.5	11.8	11.2
5	6.1	9.5	5.9
6	3.7	5.9	5.1
7	2.4	5.9	2.1
8	3.7	3.5	2.4
9	0.0	0.0	1.4
≥10	12.2	12.9	16.3
Unknown	12.2	8.2	9.1
TOTAL	**100.0**	**100.0**	**100.0**

When and Where in a Dive Problems Occurred

Tables 8.4 and 8.5 show the approximate phase of the dive (when) and the area in the water column (where) the problem occurred that subsequently led to the fatality. This information is based on witness accounts and investigative reports.

Pre-dive and many of the post-dive events are frequently associated with pre-existing health problems, such as cardiovascular disease. Incidents that occur on the surface before descent or early in the dive are often associated with malfunctioning or improperly assembled equipment. Most commonly, problems occurring late in the dive
or during ascent arise from a lack of air: 15 diving fatalities (18.3 percent) were directly attributed to insufficient air supply. "Unobserved" involves cases where the incident was not witnessed, while "unknown" refers to cases for which there was no available information.

Summary

■ To calculate the true incidence of diving injuries and fatalities, it is necessary to know how many uneventful dives occur each year. For 1997, as in previous years, this is not known.

Table 8.4 *When Problem Occurred*

	1997	1996	93-95
Post Dive	25.6	20.0	17.7
Late Dive	19.5	30.6	27.2
Unobserved	18.3	16.5	22.1
Mid Dive	12.2	15.3	9.7
Early Dive	11.0	12.9	12.7
Surface - Predive	7.3	1.2	5.5
Unknown	6.1	3.5	3.8
Upon Entry	0.0	0.0	1.3
TOTAL	**100.0**	**100.0**	**100.0**

Table 8.5 *Where Problem Occurred*

	1997	1996	93-95
Surface Post Dive	28.0	28.2	21.1
At Depth	20.7	21.2	25.9
Unobserved	19.5	15.3	20.4
During Ascent	15.9	24.7	17.9
Surface-Predive	7.3	1.2	5.5
Unknown	4.9	3.5	3.5
Descent	3.7	5.9	5.7
TOTAL	**100.0**	**100.0**	**100.0**

Fifteen fatalities (18.3 percent) in 1997 were directly attributed to the diver's running out of air.

■ DAN has initiated a pilot project, Project Dive Exploration (see Page 8) to more accurately determine the number of dives performed each year. The data collection portion of the project officially began in January 1998.

■ Each year DAN's fatality database includes cases for which little information is known about the incident or the body is not recovered.

■ A significant number of fatalities involved divers who were in the water unaccompanied. The contributing factors and circumstances surrounding these fatalities are not known and do not appear in DAN's database.

Dive Fatalities Among Certified Divers – Section 9

This section reports on the fatalities involving certified divers and those who were students in an initial, open-water certification course. The divers who had an unknown level of certification are included in this section, but the four uncertified divers have been excluded from the data presented here.

The 14 female fatalities represent 18 percent of all of 1997 scuba deaths, virtually unchanged from 1996's 18.3 percent.

Age and Gender in Diver Fatalities

The ages and the genders for the 78 certified divers who died are shown in Table 9.1 (below). The 14 female fatalities represent 18 percent of all of the 1997 scuba deaths, virtually unchanged from 18.3 percent in 1996. This information will become more meaningful only when the proportion of dives made by women each year is known.

The age range for female divers in the database was 32 to 71 years old; males ranged from 14 to 67 years of age. The age distribution is similar to that observed in the 1996 database, with the exception that in 1997 two fatalities involved individuals younger than 20 years old. Similar to what DAN reported in the previous two years, the greatest number of diving fatalities in 1997 occurred in the age group 30 to 39 years of age.

The greatest number of diving fatalities in 1997 occurred in the 30- to 39-year-old age group.

Table 9.1 *Age and Gender Comparison of 1997 Fatalities*

Age	Male	Female	Total	Percent
10 - 19	2	0	2	2.6
20 - 29	11	0	11	14.1
30 - 39	18	4	22	28.2
40 - 49	14	4	18	23.1
50 - 59	14	3	17	21.8
60 - 69	5	2	7	8.9
70 - 79	0	1	1	1.3
TOTAL	**64**	**14**	**78**	**100.0**

Certification Levels Among Fatalities

Table 9.2 shows the level of certification among the 1997 scuba fatalities. Compared to previous years, the experience levels of individuals involved in 1997 diving fatalities are more wide-ranging. Despite the large number of cases for which dive experience levels are unknown, more fatalities involved divers with greater experience than in previous years. Without knowing how many dives were performed by individuals in the different experience levels, no definite conclusions regarding the relationship between diving experience and a fatal dive mishap can be drawn. One diver in 1997 possessed junior-open water certification; this fatality is included in the open water / basic category.

Despite the large number of cases for which dive experience levels are unknown, more fatalities involved divers with greater experience than in previous years.

Table 9.2 *Certification Level of 1997 Fatalities*

Certification Level	Total	Percent
Open Water/Basic	27	34.6
Unknown	20	25.6
Advanced	11	14.1
Dive Master	6	7.7
Student*	6	7.7
Instructor	3	3.8
Cave Diver	2	2.6
Master Diver	1	1.3
Military	1	1.3
Rescue	1	1.3
TOTAL	**78**	**100.0**

** Under initial training or in a scuba familiarization course.*

Fatalities Grouped by Experience Levels

Table 9.3 shows the experience level of all certified divers involved in fatal diving accidents based on reported lifetime dives, a number gleaned from the information reported to DAN. These numbers are not always exact and are sometimes difficult to obtain. Some divers keep meticulous logbooks, while others estimate their number of lifetime dives, and this figure may not be known by dive partners or family members. The experience level in this table is indicated by categories containing a range of dives and designated by titles ranging from "novice" to "experienced."

Some divers keep very meticulous log-books while others merely estimate their number of lifetime dives.

Table 9.3 *Diving Experience During Diving Activity*

	Overall Experience		Within Activity or Environment	
	Total	Percent	Total	Percent
Student	6	7.7	11	14.1
Novice (≤ 5 dives)	4	5.2	4	5.1
Inexperienced (6 - 20 dives)	18	23.1	17	21.8
Intermediate (21 - 40 dives)	3	3.8	4	5.1
Advanced (41 - 60 dives)	3	3.8	4	5.1
Experienced (≥ 61 dives)	34	43.6	25	32.2
No experience	0	0.0	3	3.8
Unknown	10	12.8	10	12.8
TOTAL	**78**	**100.0***	**78**	**100.0***

* *Percent of certified divers*

The most fatalities in any single experience group occurred among those divers with 61 or more dives.

41 percent of all 1997 diving fatalities involved divers with 20 or fewer dives.

Other indicators of diving experience include the number of years a diver has been certified and how many dives he or she has made during the preceding year. Unfortunately, in most cases, this information is not known or is inexact. Another factor considered to figure highly in diving mishaps is the diver's familiarity with the activity or environment.

Table 9.3, above, shows eight levels of experience. Based on the overall level of training and numbers and types of dives done, each fatality was placed in a category as noted in the "Overall Experience" columns. However, at the time of the fatality, a diver may have been engaged in a specific activity in which his experience level differed from his overall experience. For instance, 11 divers died while diving as a student, even though some had more overall experience. An example of this would be an advanced diver who died while being trained in a new diving activity, such as mixed-gas diving. Twenty-five of the 34 fatalities in the "Experienced" category (≥61 dives) were engaging in the specific type of diving for which they had been trained. While all divers had some level of experience, three divers died performing a specific type of dive in which they had no experience (i.e., during a mixed-gas dive) and when they had no training in that type of diving. Information on experience levels is obtained from family, witnesses and investigative reports.

As in previous years, the most fatalities in any single experience-level group occurred among divers with 61 or more lifetime dives. When interpreting this figure, it must be kept in mind that this group represents the most active divers, who likely are logging the most

bottom time each year. Additionally, more experienced divers tend to engage in more challenging dive activities. DAN can only speculate on whether a certain level of complacency has resulted in any of the fatalities that occurred among divers with the most experience. A significant fact remains: 41 percent of all recreational diving fatalities in 1997 involved divers who had made 20 or fewer dives.

The number of fatalities involving students in an initial open-water certification course was four, down from the six deaths reported in 1996; and the number of newly certified divers in the fatality database decreased from nine in 1996 to four in 1997. The number of deaths that involved divers who were either students in an advanced, dive-training course or those who were diving in unfamiliar environments remained consistent from 1996 to 1997.

The "inexperienced" group consistently has had the greatest number of fatalities in the "Within Activity or Environment" category. It is possible that many divers are moving on to less familiar surroundings before obtaining a sound level of expertise in basic diving skills. Increased training in basic and advanced diving skills should result in a decrease in the total number of diving fatalities.

The inexperienced group consistently has had the greatest number of fatalities in the "Within Activity or Environment" category.

To report an injury, a fatality or a near-miss in diving, call DAN's Medical Department at +1-919-684-2948 or 800-446 2671.

Divers Alert Network
The Peter B. Bennett Center
6 West Colony Place
Durham, NC 27705

Appendix A

1997 Fatality Case Reports with Autopsy Findings

By James Caruso, M.D., DAN On-Call Volunteer Physician

Introduction / Overview

During the reporting year of 1997, Divers Alert Network collected information on 82 scuba diving-related fatalities. In five cases, a body was not recovered; an autopsy was not performed in four other cases that were reported to DAN; and seven cases did not have enough information to determine if an autopsy was performed. In an additional nine cases, an autopsy was performed, but little or no information regarding the findings of the post-mortem examination was made available.

As stated in previous years, the purpose of this section is to use the case summaries to describe factors which may have contributed to fatal diving mishaps. This allows training agencies and other organizations involved in diver education to identify areas where increased training may result in the prevention of injury or death. Diver education is a major function of Divers Alert Network, and our hope is to prevent future mishaps by reviewing the circumstances associated with fatal outcomes.

In this section, the causes of death and the factors contributing to the death are listed using the terminology of the International Classification of Diseases Clinical Modification (ICD-9-CM) based on the World Health Organization's International Classification of Diseases [1]. DAN has adapted a few of the environmental (the numbers preceded by an E) codes to make them more specific for describing some of the contributing causes of death in diving fatalities. The most frequently used codes are listed in Appendix F (Page 123).

The summaries and final anatomic diagnoses are arrived at by correlating all available information accumulated by DAN. This includes statements by witnesses and dive buddies, police and U.S. Coast Guard reports, DAN accident report forms and the autopsy report. DAN is indebted to many sources for gathering and contributing information on diving fatalities. Their cooperation is essential in our effort to put together this section. In most cases, the cause of death reported in the Fatality Case Report agrees with the conclusion arrived at by the medical examiner. In a select few cases, however, there is substantial historical or clinical evidence upon which an alternative cause of death can be based. The level of experience and familiarity with diving mishaps varies greatly among medical examiners and forensic pathologists.

The investigation of a diving fatality should include a minimum of the following information:

- The decedent's past medical history and any medications taken on a regular basis;
- The decedent's level of training and diving experience;
- Any witness statements about the decedent's physical and emotional state on the day of the mishap;
- The dive profile, including the depth and bottom time of the dive, where and when the decedent began to run into difficulty, and any history of dives completed earlier in the day;
- Resuscitation efforts performed and the decedent's response, if any, to therapy;
- The findings of a complete autopsy, including toxicology results;
- The results of an examination of the decedent's equipment, including analysis of the breathing gas used, if available.

Special techniques can be used to maximize the amount of information gained during the post-mortem examination of a suspected diving fatality victim. The autopsy protocol included as Appendix B (Page 109) is a modification of a protocol that originally appeared in the 1992 *Report on Diving Accidents and Fatalities* [2]. It is recommended that this protocol be used as a guideline when performing post-mortem examinations on diving fatality victims. Erroneous conclusions are occasionally drawn from obtaining air through a simple thoracic puncture or seeing bubbles distributed within the cerebral and coronary vessels and the vena cava. Intravascular gas

is not conclusive evidence supporting a diagnosis of air embolism or decompression sickness in someone who was breathing compressed air prior to death. All available pieces of information, especially those items listed above, should be taken into consideration before arriving at a conclusion regarding the cause of death in a diving fatality.

Diving fatalities are nearly always initially categorized as non-natural deaths, and in most states the medical examiner system assumes jurisdiction over the case. Autopsies are performed at the discretion of the medical examiner. In most cases, a post-mortem examination is ordered. It is recommended that a complete autopsy be performed in all diving fatalities and accidental drownings. The final event in most diving fatalities is drowning, but the circumstances and events that resulted in the drowning are far more important pieces of information. Furthermore, drowning is basically a diagnosis of exclusion. It may be argued that without a complete post-mortem examination, many possible causes of death have not been excluded[3].

A total of 57 fatality case reports had an autopsy that was available to DAN for review. These cases appear in the following pages, categorized according to the immediate cause of death. Cases are identified by a code number, and patient confidentiality is strictly maintained. Nine cases included an autopsy, but the findings were not made available to DAN. Four cases did not include a post-mortem examination, and seven did not have enough information to make a determination. Five cases involved fatalities where a body was never recovered. These other categories of cases are presented after the section on autopsied cases and the same classification scheme is used.

Autopsied Cases

A total of 57 fatality case reports with autopsy findings appear in the following sections. The autopsy provided critical information in establishing the cause of death in these cases. Divers are a self-selected group, and the epidemiological data on divers cannot be extrapolated to the general population. We must, however, take note of commonly occurring errors in judgment and pre-existing health problems that appear in these case reports.

Contributing Factors: Cardiovascular Disease and Inexperience

At the 1997 Scientific Meeting of the Undersea and Hyperbaric Medical Society, DAN presented data showing the high incidence of cardiovascular disease among diver fatality victims. Cardiovascular disease continues to be a significant cause of death or contributing factor to the primary cause of death in a large percentage of diving fatalities[4]. Cardiovascular disease is the number one cause of death for both men and women in the United States and most developed countries[5]. The diver with atherosclerotic coronary artery disease is at increased risk for a myocardial infarction or sudden cardiac death.

Of the 57 cases for which we have autopsy information in 1997, nine included cardiovascular disease as the primary cause of death or as a contributing factor to the primary cause of death. In several other cases, incidental coronary atherosclerosis was noted during the post-mortem examination. Most recreational diving is not considered strenuous exercise, but there is always a component of physical activity and occasional exertion involved. A greater level of physical activity may be required under certain circumstances, such as swimming against a strong current or assisting another diver. A diver may need to call on some physical reserve in order to extricate him- or herself from a difficult situation. Additionally, diving can take place in areas that are remote from a tertiary medical care facility, and the mere fact that the diver is in the water makes surviving a cardiac event much less likely.

Diving should be considered a potentially strenuous activity and one that requires an adequate level of physical and cardiovascular fitness. Prior to entering initial diving training, individuals would be wise to have their health and fitness status reviewed by a physician. Older individuals who desire either to continue diving or wish to participate in an initial diving certification class should have a thorough physical examination with appropriate assessment of their cardiovascular fitness. An electrocardiogram and exercise treadmill test are strongly encouraged.

Inexperienced divers were over-represented among the fatalities reviewed by DAN from 1991 to 1994[6], and that trend continued in 1997. Inexperienced divers include divers who are in their initial open-water certification course and those divers who have performed 20 or fewer open-water dives after

completing their training. As in previous years, between 35 and 40 percent of the fatalities involved inexperienced divers in 1997. DAN estimates that Project Dive Exploration will provide some insight with regard to how many dives are being made by divers of the different levels of experience, allowing more meaningful interpretation of this data. Despite the inability to apply sound statistical methods to the data, it is safe to say that inexperienced divers are over-represented in the dive fatality database.

DAN presented data that examined level of experience of divers involved in a diving fatality at the 1998 annual scientific meeting of the Undersea and Hyperbaric Medical Society.

More than 700 diving fatalities were reviewed; the following items are noteworthy[7]:

- 5.4 percent of all fatalities involved students in an initial open water certification course;
- 26.7 percent of all dive fatalities involved certified divers who had made 20 or fewer lifetime dives.

Clearly, novice divers should dive within their skill level and practice conservative diving habits as they gain experience and seek advanced training.

Many experienced divers continue to experience difficulty when they stretch the limits of their training and attempt specialty dives, such as cave exploration and wreck penetration, without formal training. These types of dives require specialized equipment, sound dive planning, and redundant backup emergency systems. Formal training is essential prior to participating in these more specialized types of dives. The importance of proper training and a thorough familiarity with all equipment used during the dive cannot be overemphasized.

Summary of Fatality Data Collection

The primary reason for collecting and publishing DAN fatality case studies is to help avoid future injuries. We can educate ourselves and our fellow divers by sharing the lessons learned from the unfortunate experiences of others. If we are successful in our efforts, those of us at DAN would like to be able to have nothing to report in the fatality section of future reports. In order to accomplish this goal, DAN advocates the following:

- Physical fitness and proper nutrition;
- Appropriate training and education;
- Proper and well-maintained equipment;
- Safe and conservative diving habits.

Promoting these precepts to divers of all levels, from novice to instructor, can help reach DAN's goal of safer diving for everyone.

The 1997 database of scuba diving fatalities can be found on the following pages.

LEGEND FOR FATALITY SUMMARIES	
R: Recreational diver	**R/T:** Recreational/Technical diver (conducting a technical dive not qualified for)
T: Technical diver	**U:** Uncertified diver (without a scuba certification from a national agency)
S: Student diver	**UNK:** Unknown certification

Decompression Illness

The term "decompression illness" (DCI) includes the two bubble-related diseases most identified with diving — decompression sickness (DCS) and arterial gas embolism (AGE).

These disorders are grouped together because they are both characterized by:

- The presence of bubbles;
- A pressure change being required to produce the disease; and
- Similar treatment.

The 1997 autopsy series in the DAN database includes one fatality due to decompression sickness. DCS is an infrequent cause of death in diving, but it can result in permanent disability and even paralysis. When DCS does result in death, the victim usually succumbs to complications of a prolonged hospitalization and the multiple medical problems that accompany the process (e.g., respiratory distress syndrome, disseminated intravascular coagulation or pulmonary embolism). The 1997 fatality is unusual in that the diver died of severe DCS shortly after completing his dives.

There were 12 fatalities due to air embolism and an additional six cases of drowning secondary to air embolism in 1997. In many cases, these fatalities involved inexperienced divers — running out of air and panic were frequently part of the scenario. Inexperience is also a contributing factor in cases of divers who survive an arterial gas embolism[8].

During initial dive certification training, buoyancy control and slow ascent rates cannot be overemphasized. Divers must gain a high level of comfort and familiarity with their equipment and emergency procedures. There is seldom, if ever, a good excuse for running out of air, and the results can be catastrophic.

Decompression Sickness

DAN RECORD NO: 3797 **AGE:** 48 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Decompression sickness, severe	993.3
Due to: Scuba diving	E910.1

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

Left ventricular hypertrophy	429.3
Pulmonary emphysema	492.8

Autopsy (Y/N): Y Findings available (Y/N): Y

This is one of those rare cases of fatal decompression sickness. A 48-year-old very experienced male diver made seven consecutive dives to an average depth of 90 fsw. The diver's bottom time was dictated by how long his tank of air lasted. He was spearfishing and had found a large school of game fish. The diver was alone in the water while a non-diver waited behind in the boat. His boat had no radio and was ill equipped for emergencies. After the series of dives, the decedent reported that he felt poorly and re-entered the water to "decompress." He was barely able to get back into the boat after the last period at depth and asked the other person in the boat to start heading back to shore. After a series of boat transfers and with the assistance of the U.S. Coast Guard, the diver was taken to a recompression chamber where therapy was initiated. The diver's condition progressively worsened during the transfer and treatment period. He was pronounced dead several hours after arriving at the chamber. The autopsy report lists an air embolism as the cause of death, but there is nothing in the history or autopsy findings that would lead to the conclusion that this fatality was due to anything but massive decompression sickness.

Air Embolism

DAN RECORD NO: 397 **AGE:** 32 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Cerebral air embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.

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

Coronary atherosclerosis	414.0
Subcutaneous emphysema	958.7
Fatty liver	571.8

Autopsy (Y/N): Y Findings available (Y/N): Y

This experienced 32-year-old male diver was working on his divemaster certification. He and another diver were making dives on a wreck and spearfishing at 140 fsw when the decedent became low on air. The two divers buddy-breathed properly until they had ascended to 50 fsw. At this time the decedent ascended much more quickly. He was seen on the surface with the regulator out of his mouth, and he rapidly lost consciousness. Resuscitation efforts were unsuccessful.

DAN RECORD NO: 1697 **AGE:** 25 **SEX:** M **DIVER CAT:** S

Cause of Death	**ICD-9-CM**
Immediate: Air Embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Scuba Diving	E910.1

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

Pulmonary barotrauma	518.1
Coronary atherosclerosis, mild	414.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 25-year-old male was a student in an initial open water diving course and was making his last dive prior to certification. During emergency ascent training from approximately 20-25 fsw the decedent spit his regulator out. He was confused and disoriented on the surface, complained of numbness and parasthesias, and rapidly lost consciousness. Resuscitation efforts were unsuccessful. The autopsy revealed evidence of pulmonary barotrauma as well as air in the superficial vessels of the brain. The intravascular gas is not definitive, but the dive history, clinical presentation and corroborating pulmonary barotrauma make air embolism the cause of death in this case.

DAN RECORD NO: 1797 **AGE:** 47 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Arterial gas embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Toxicology positive for cannabinoids	E980.3

Autopsy (Y/N): Y Findings available (Y/N): Y

This 47-year-old male was an experienced diver who went to 95 fsw without a buddy. He admitted to making a rapid ascent after seeing a shark and did not feel well upon getting back into the boat. Shortly thereafter the diver lost consciousness and could not be resuscitated. There are conflicting reports regarding whether the decedent ran out of air as well.

DAN RECORD NO: 1897 **AGE:** 36 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Air embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Panic	308.0
Pulmonary barotrauma	518.1

Autopsy (Y/N): Y Findings Available (Y/N): Y

This 36-year-old male had been certified for one year and had made less than 20 dives. After an initial dive to 82 fsw, the decedent and his dive buddy made a decompression dive to 130 fsw. The decedent had some unspecified trouble with his gear, and the buddy watched him ascend rapidly. The dive buddy assisted the decedent into the boat and called for assistance. The diver was airlifted to a medical facility where he was pronounced dead on arrival. The autopsy disclosed abundant intravascular gas and evidence of pulmonary barotrauma.

DAN RECORD NO: 2897 **AGE:** 58 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Anoxic brain damage	348.1
Due to: Arterial gas embolism	958.0
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Cavernous hemangioma, liver	228.04
Chronic prostatitis	601.1
Renal cysts	593.2

Autopsy (Y/N): Y Findings available (Y/N): Y

This 58-year-old male was making his second dive of the day to 91 fsw using nitrox. He was an experienced diver, but had no nitrox diving certification. During the first dive, the decedent ran out of air and needed to buddy breathe. He was required to change buddies for the second dive and entered the water with two other divers, neither of whom was designated as his dive buddy. At the completion of the second dive, the decedent was seen on the surface, apparently doing well. He then appeared to be disoriented and rapidly lost consciousness. The diver was resuscitated and transferred to a local hospital and finally to a facility with a recompression chamber. He was pronounced dead prior to any hyperbaric oxygen therapy. An evaluation of the decedent's gear revealed that the tank from his second dive was empty as well.

DAN RECORD NO: 3297 **AGE:** 41 **SEX:** M **DIVER CAT:** T

Cause of Death	**ICD-9-CM**
Immediate: Arterial gas embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Scuba diving	E910.1

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

Pneumomediastinum	518.1
Tension pneumothorax	512.0
Left ventricular hypertrophy	429.3
Hypertension	401.9
History of depression	296.2

Significant Incidental Diagnoses

Cholelithiasis	574.2

Autopsy (Y/N): Y Findings available (Y/N): Y

This 41-year-old male was a certified cave diver making a cave dive to 91 feet in a freshwater spring. He experienced some problem at depth and seemed to indicate that his dry suit was too tight. The decedent made a witnessed rapid ascent and was unconscious on the surface. He was transferred to a local medical facility where he was pronounced dead several hours later. The decedent was never stable enough to transport to a hospital that has a recompression chamber. The autopsy revealed evidence of pulmonary barotrauma as well as gas embolism.

DAN RECORD NO: 4297 **AGE:** 38 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Arterial gas embolism	958.0
Due to: Scuba diving	E910.1

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

Mediastinal emphysema	518.1
Subcutaneous emphysema	958.7
Coronary atherosclerosis, moderate	414.0
Tobacco abuse	305.1
Hypertension	401.9
Cannabinoids on toxicology	E980.3
Nitrogen narcosis	293.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 38-year-old male was a longtime, active diver but it is unknown what his certification level was. He had a serious decompression hit in 1995. The decedent and two other divers made three dives, all to greater than 140 fsw. During the ascent from the third dive, the decedent appeared to stay below the other two divers after they had all agreed to ascend. The dive buddies then remember seeing the decedent above them on the surface while they made their decompression stops. The autopsy disclosed evidence of pulmonary barotrauma and intravascular gas. The gas may be due to an air embolism or just the consequence of making deep, decompression dives. The evidence of barotrauma and history lead me to conclude that this was an air embolism.

DAN RECORD NO: 4997 **AGE:** 33 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Air embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Nitrogen narcosis	293.0
Due to: Scuba diving	E910.1

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

Mediastinal and subcutaneous emphysema	518.1

Significant incidental diagnoses

Fatty Liver	571.8
Cholelithiasis	574.2

Autopsy (Y/N): Y Findings available (Y/N): Y

The facts of this fatality are unknown with certainty as there are conflicting stories from witnesses and participants. This 33-year-old male diver with two years of experience and divemaster certification was under instruction to make deep dives on air. He had previously logged air dives to depths of greater than 150 feet. While at 190 feet with three other

divers, the decedent reportedly experienced problems with his wet suit and/or regulator. He was also reported to have lost consciousness. Other divers coming to his aid initially attempted buddy breathing before inflating the decedent's buoyancy compensator and sending him to the surface. The decedent made an uncontrolled ascent, possibly while unconscious, before sinking back down below the surface. The autopsy revealed evidence of pulmonary barotrauma as well as findings consistent with drowning.

DAN RECORD NO: 5497 **AGE:** 57 **SEX:** F **DIVER CAT:** S

Cause of Death	**ICD-9-CM**
Immediate: Arterial gas embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Scuba diving	E910.1

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

Coronary atherosclerosis, moderate	414.0
Morbid obesity	278.0
Uterine leiomyomas	219.9

Autopsy (Y/N): Y Findings available (Y/N): Y

This 57-year-old female was a student in an initial open water certification class making her last dive prior to receiving her qualification card. The decedent collapsed right after getting back into the boat and could not be resuscitated. The autopsy ascribes the cause of death to an air embolism, which is purely based on the classic history of a catastrophic collapse directly following an ascent from a dive.

DAN RECORD NO: 5597 **AGE:** 12 **SEX:** M **DIVER CAT:** U

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

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

Mediastinal emphysema	518.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 12-year-old male had no formal dive training, but had made 10-15 dives with his father. Sometimes he used his own regulator, but nearly half the time he would descend without dive equipment and share an air source with his father. On this occasion, he was sharing his father's air and went to a depth of 20 feet. The boy surfaced with his father directly behind him. Upon reaching the surface, the boy screamed and rapidly lost consciousness. Resuscitation efforts were unsuccessful.

DAN RECORD NO: 6597 **AGE:** 50 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Hypoxic encephalopathy	348.1
Due to: Air embolism	958.0
Due to: Scuba diving	E910.1

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

Panic	308.0
Left ventricular hypertrophy	429.3
Fatty liver	571.8
Cirrhosis	571.5

Autopsy (Y/N): Y Findings available (Y/N): Y

This 50-year-old male obtained his diving certification 20 years earlier and had only recently renewed his interest in diving. He was a student in an advanced open-water class and made a dive to 90 feet with a group of seven other divers. After five minutes on the bottom, the decedent signaled that he wanted to ascend. He reportedly made a controlled ascent with an instructor, but was unresponsive when they arrived at the surface. The diver was resuscitated and treated in a local hyperbaric chamber, but he died three days later. The cause of death was listed as an air embolism, but the history is incomplete. An AGE during ascent may have occurred; it is unclear what problem required the diver to ascend in the first place.

DAN RECORD NO: 7997 **AGE:** 30 **SEX:** M **DIVER CAT:** R

Cause of Death		**ICD-9-CM**
Immediate: Cerebral air embolism	958.0	
Due to: Rapid ascent		E902.2
Due to: Scuba diving		E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:		
Left ventricular hypertrophy		429.3
Cirrhosis		571.2
Fatty liver		571.8

Autopsy (Y/N): Y Findings available (Y/N): Y

This 30-year-old male with extensive diving experience made a night dive to 65 fsw for 40 minutes. It is unclear what prompted the diver to drop his weight belt and rapidly go to the surface. He appeared lethargic on the surface, began to cough and quickly became unconscious. The diver was pronounced dead at a local hospital. An autopsy disclosed subcutaneous emphysema as well as gas in the cerebral and coronary vessels. An investigation of the decedent's diving experience revealed that he may have never received formal certification.

Drowning With Air Embolism

DAN RECORD NO: 1097 **AGE:** 34 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Air embolism	958.0
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 34-year-old male had made only five lifetime dives when he planned a wreck dive down to 80-100 feet in a large freshwater lake. During the dive, both the decedent and his buddy ran low on air. As they ascended, the decedent stopped before reaching the surface and seemed to be having a buoyancy problem. The dive buddy was out of air and had to continue toward the surface. After getting a full tank, the dive buddy went back down and pulled the decedent off of the bottom. Resuscitation efforts were unsuccessful. The autopsy was performed the next day and revealed air in the right side of the heart which could be from the depth and bottom time of the dive and is not diagnostic of air embolism. Other findings were consistent with drowning.

DAN RECORD NO: 2597 **AGE:** 34 **SEX:** M **DIVER CAT:** R

Cause of Death		**ICD-9-CM**
Immediate: Drowning		994.1
Due to: Air embolism		958.0
Due to: Insufficient air		E913.2
Due to: Scuba diving		E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:		
Pneumothorax		860.0
Coronary atherosclerosis, moderate		414.0
Significant incidental findings:		
Fatty Liver		571.8

Autopsy (Y/N): Y Findings available (Y/N): Y

This very experienced, but infrequent, 34-year-old male diver was making his first dive of the year at the beginning of lobster season. After an uneventful first dive, he complained of some neck and shoulder pain. The decedent then made a second dive during which he and his buddy became low on air. The two divers separated because the buddy was lower on air and the decedent decided to continue the dive. The decedent was next seen unconscious and floating on the surface. An autopsy was performed after organs were harvested for transplantation. There was evidence of pulmonary barotrauma as well as intravascular gas. The medical examiner concluded that the death was due to both air embolism and decompression sickness, but the dive profiles were reasonable and the decedent's upper torso pain was more likely due to muscle strain and lack of physical activity and conditioning. A finding of intravascular gas at an autopsy after the organs have been harvested can be difficult to interpret.

DAN RECORD NO: 4697 **AGE:** 51 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Air embolism	958.0
Due to: Scuba diving	E910.1

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

Bronchial asthma, acute exacerbation	493.9
Mediastinal emphysema	518.1
Subcutaneous emphysema	958.7
Hypertension	401.9
Obesity	278.0
Left ventricular hypertrophy	429.3
Coronary atherosclerosis, mild	414.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 51-year-old male was recently certified in an initial open water course. He had developed asthma two years earlier and used an inhaler prior to entering the water to dive. The decedent was making a dive to a maximum depth of 55 fsw with three other divers, including the divemaster. He and the divemaster found themselves ahead of the other two divers so the divemaster instructed the decedent to wait while he went back to get the other divers. When the three divers returned to the spot where the decedent was to be waiting, he was nowhere in sight. He was found on the surface floating near shore and was pronounced dead at the local recompression chamber. The autopsy disclosed evidence of pulmonary barotrauma as well as an exacerbation of his reactive airway disease.

DAN RECORD NO: 6797 **AGE:** 44 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Air embolism	958.0
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.1

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

Mediastinal emphysema	518.1

Significant incidental findings:

Gallbladder polyp	211.5

Autopsy (Y/N): Y Findings available (Y/N): Y

This 44-year-old experienced female diver had not made a dive during the previous two years. She made a dive to 75 fsw with three other divers. During the ascent, the decedent ran out of air and began to buddy breathe. She lost consciousness prior to reaching the surface and slipped back to the bottom. The decedent was brought up to the surface, but could not be resuscitated. The other two divers were also buddy breathing during their ascent. The autopsy disclosed intravascular gas and evidence of pulmonary barotrauma. The history completely corroborates the diagnosis of air embolism.

DAN RECORD NO: 7297 **AGE:** 36 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Air embolism	958.0
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.1

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

Mediastinal and subcutaneous emphysema	518.1
Tobacco abuse	305.1

This 36-year-old female had obtained advanced open-water certification, but had only made 12 lifetime dives. She was part of a large group making a dive near an oil platform. There was some confusion regarding dive buddy assignments and the decedent ended up making the dive alone. After all other divers returned to the boat, a search was conducted for the decedent who was found, by Coast Guard helicopters, unconscious and floating on the surface. The diver's tank was empty and her depth gauge listed a maximum depth of 165 fsw. Resuscitation efforts were unsuccessful. Nitrogen narcosis may have also played a role in this fatality.

DAN RECORD NO: 7397 **AGE:** 14 **SEX: M** **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Air Embolism	958.0
Due to: Rapid ascent	E902.2
Due to: Insufficient air	E913.2
Due to: Scuba Diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 14-year-old boy received his junior certification just a couple of months prior to making this dive. He and his father were diving together to hunt fish with a spear gun. Both divers began the dive with less than half a tank of air and the maximum depth of the dive ended up being between 80 and 100 feet. After deciding to ascend, the father and son buddy team briefly became separated. The boy was next seen to descend below 100 feet without his regulator in his mouth. The father pulled his son up from 285 feet, but resuscitation was unsuccessful. A carefully performed autopsy revealed intracardiac gas as well as gas in the cerebral and coronary vessels.

Cardiovascular Disease

The problem of cardiovascular disease in the diving population has been addressed in the introduction. Major risk factors for coronary artery disease include smoking, a diet high in cholesterol and saturated fats, male gender, hypertension, diabetes and a family history of premature cardiovascular disease. The risk of developing cardiovascular disease increases with increasing age as well.

Exertion increases the cardiac output and the need for oxygen by the myocardium (heart muscle). If the vessels supplying blood, and ultimately oxygen, to the heart are narrowed by atherosclerosis, the result can be hypoxic damage or death of the tissue, and, potentially, a short circuit in the electrical conduction of the heartbeat.

A diver with known cardiovascular disease needs to understand the potential increased risks and possible consequences of continuing to dive. Each individual needs to make an educated decision regarding his or her participation in any recreational activity. Additionally, when performed correctly, diving is a buddy activity, and the buddy should be made aware of any significant health problems possessed by the other member of the team.

Many physicians who take care of divers will clear an individual who has undergone coronary bypass surgery for diving if the diver can remain asymptomatic while demonstrating a reasonable level of cardiovascular fitness. Older individuals who desire to continue diving or begin an initial certification course should have a thorough physical examination, including an evaluation of cardiovascular fitness.

In the following cases, many individuals had silent cardiovascular disease, which initially manifested itself during a dive with catastrophic outcomes. There is a smaller category of cases where the diver had known health problems that may have been disqualifying for diving.

DAN RECORD NO: 697 **AGE:** 49 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Acute myocardial infarction	410.9
Due to: Coronary atherosclerosis	414.0
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Left ventricular hypertrophy	429.3
Pulmonary emphysema	492.8
Hepatitis	573.3
Tobacco abuse	305.1
Morbid obesity	278.0
Scuba diving	E910.1
Significant incidental findings:	
Bile duct hamartoma	211.5
Kidney myelolipoma	211.8

Autopsy (Y/N): Y Findings available (Y/N): Y

This 49-year-old male returned to diving after an 18-year hiatus. This was his third dive after that long break, and he was under instruction. After a shallow dive, the decedent and his buddy swam back to the boat — a distance of approximately 25 yards. The decedent swam on the surface while his buddy stayed beneath the surface. The two divers became separated, and the decedent was found on the bottom and unconscious. The autopsy disclosed significant cardiovascular and pulmonary disease.

DAN RECORD NO: 797 **AGE:** 54 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Aspiration	933.1
Due to: Cardiac dysrhythmia	427.9
Due to: Coronary atherosclerosis	414.0
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Scuba diving	E910.1
Left ventricular hypertrophy	429.3
Myocardial scarring	429.0
Obesity	278.0
Tobacco abuse	305.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 54-year-old female was an experienced diver who had several chronic health problems. She made a dive to 20 fsw for 20 minutes without her dive buddy. After giving an "OK" sign on the surface and inflating her buoyancy compensator, the decedent appeared to struggle and was in obvious distress. Other divers came to her assistance, but she quickly lost consciousness and could not be resuscitated. The autopsy disclosed multiple cardiac abnormalities and evidence of aspirated stomach contents. The decedent had also undergone surgery to repair her aorta six months previously.

DAN RECORD NO: 2497 **AGE:** 57 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Cardiac dysrhythmia	427.9
Due to: Coronary atherosclerosis, severe	414.0
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Scuba diving	E910.1
Myocardial infarctions, remote	412.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 57-year-old diver had made seven lifetime dives prior to this one. He collapsed on the surface after completing the dive and could not be resuscitated. The autopsy showed evidence of significant natural disease.

DAN RECORD NO: 2697 **AGE:** 49 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Cardiac dysrhythmia	427.9
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Toxicology positive for cocaine metabolites	E980.4
Toxicology positive for cannabinoids	E980.3
Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 49-year-old male was a certified diver who made infrequent dives. He reportedly felt uneasy after entering the water and prior to descending. The diver decided to abort the dive and get back into the boat, but he collapsed while climbing up the ladder. The autopsy disclosed no significant coronary atherosclerosis; cocaine, however, commonly causes cardiac dysrhythmias.

DAN RECORD NO: 3197 **AGE:** 49 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Cardiac dysrhythmia	427.9
Due to: Antihistamine/decongestant overdose	975.6

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

Myocardial fibrosis	429.0
Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

There is little information about the dive experience and dive profile of this 49-year-old male certified diver. He had some difficulty equalizing middle ear pressures during the decent to 40 fsw. He was later seen on the surface and appeared to have difficulties during the swim back to the boat. The decedent disappeared below the surface and, after being pulled from the water, could not be resuscitated. The autopsy revealed evidence of cardiac disease, but the toxicology report contained the most significant findings. The decedent had more than 10 times the therapeutic level of chlorpheniramine and more than 20 times the therapeutic level of phenylpropanolamine in his blood.

DAN RECORD NO: 7097 **AGE:** 53 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Cardiac dysrhythmia	427.9

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

Myocardial infarction, remote	412.0
Left ventricular hypertrophy	429.3
Hypertension	401.9
Seizure disorder	780.3
Hemorrhagic gastritis	535.5
Tobacco abuse	305.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 53-year-old male had been diving for three years while taking anticonvulsive medications. He surfaced after a dive to 50 fsw for 40 minutes and told a witness that he was not doing well before he became unconscious. The cause of death was listed as drowning with a cardiac dysrhythmia the most likely precipitating event. A seizure cannot be completely excluded.

DAN RECORD NO: 7597 **AGE:** 46 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Cardiac dysrhythmia	427.9
Due to: Coronary atherosclerosis, severe	414.0

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

Left ventricular hypertrophy	429.3
Hypertension	401.9
Obesity	278.0
Scuba diving	E910.1

Significant incidental findings:

Renal cortical cysts	593.2
Lymphocytic thyroiditis	245.2

Autopsy (Y/N): Y Findings available (Y/N): Y

This 46-year-old male certified diver had planned to dive with two other people, but entered the water alone in order to check the visibility. After making a shore entry the decedent appeared to head in the opposite direction from where he had told the other divers he would head. Within minutes he surfaced, appeared to be in obvious distress and then submerged again. The other divers came to the decedent's rescue and attempted to resuscitate him, but were unsuccessful. The autopsy revealed evidence of extensive cardiac disease.

DAN RECORD NO: 7697 **AGE:** 50 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Cardiac dysrhythmia	427.9
Due to: Coronary atherosclerosis, severe	414.0

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

Obesity	278.0
Diabetes mellitus	50.0
Hypertension	401.9

Left ventricular hypertrophy	429.3
Fatty liver	571.8
Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 50-year-old male was a certified diver with a moderate level of experience. He entered the water from a rocky shoreline, but before he could descend he was caught in the rough surf. The decedent's dive buddy came to his aid, but the diver had lost consciousness and was never resuscitated. The autopsy disclosed evidence of several natural disease processes.

DAN RECORD NO: 8297 **AGE:** 49 **SEX:** M **DIVER CAT:** S

Cause of Death	**ICD-9-CM**
Immediate: Cardiac dysrhythmia	427.9
Due to: Coronary atherosclerosis, severe	414.0

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

Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 49-year-old male was a participant in a resort scuba familiarization course. He had made two previous lifetime dives, but had no formal certification. After completing a 12-minute dive to 42 fsw, he was seen on the surface, in noticeable distress. The decedent lost consciousness and was transferred to the hyperbaric chamber where he was pronounced dead soon after initiating recompression therapy. A partial autopsy report indicates significant coronary artery disease and the case was signed out as a cardiac event.

Drowning Due to Insufficient Air

The following cases are placed together because they represent instances when running out of breathing gas directly resulted in the diver's drowning. Cases where insufficient gas was only one of several factors contributing to the fatality (e.g., entrapment in a cave) have been placed in other categories. These eight fatalities occurred because the individual did not complete the dive with a sufficient reserve of breathing gas. Most dive training organizations recommend that divers be on the surface or on the boat with at least 300-500 psi in their tank as a margin of safety.

DAN RECORD NO: 597 **AGE:** 28 **SEX:** M **DIVER CAT:** R

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

Autopsy (Y/N): Y Findings available (Y/N): Y

This 28-year-old male was an experienced, certified diver. He and a dive buddy made a shallow dive, but had to surface far from the boat because they ran out of air. The decedent became extremely fatigued during the surface swim and the buddy continued toward the boat without him. The dive buddy had some difficulty starting the boat and he lost sight of the decedent approximately 75 yards away from the vessel. The body was recovered two days later. In addition to an empty tank, the decedent still had his weight belt on but had removed his buoyancy compensator.

DAN RECORD NO: 1497 **AGE:** 62 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Hypoxic encephalopathy	348.1
Due to: Insufficient air	E913.2
Due to: Near drowning	994.1
Due to: Scuba diving	E910.1

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

Adult respiratory distress syndrome	518.5
Pneumonia	482.9
Coronary atherosclerosis, mild	414.0
Left ventricular hypertrophy	429.3

Autopsy (Y/N): Y Findings available (Y/N): Y

This 62-year-old male was an experienced diver who was making a dive to 108 fsw on a wreck. He ran out of air and was buddy breathing with another diver when the other diver ran out of air as well. Other divers came to the assistance of both men, but the decedent would not let go of the anchor line and did not take an alternate air source when it was offered to him. The decedent became unconscious on the bottom and was brought to the surface and transported to a local hospital. After he was taken to a hospital with a hyperbaric chamber, the decedent was treated with hyperbaric oxygen for a possible air embolism. He never regained consciousness, and brain death was declared 36 hours later.

DAN RECORD NO: 1597 **AGE:** 49 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Panic	308.0
Tobacco abuse	305.1
Obesity	278.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 49-year-old female had been certified for only one week and had made less than five lifetime dives. She was making a few additional dives with her instructor for the purpose of gaining confidence in the water. The diver became separated from her buddy twice during the dive. After the second separation, the other divers exited the water and waited for the decedent to surface. Fifteen minutes later, the decedent was seen on the surface, struggling and calling for assistance. The instructor swam out to her, but she disappeared below the surface. The body was recovered more than an hour later. The autopsy findings were consistent with drowning and there was no evidence of pulmonary barotrauma or intravascular gas.

DAN RECORD NO: 3397 **AGE:** 57 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Coronary atherosclerosis, moderate to severe	414.0
Rapid ascent	E902.2
Significant incidental findings:	
Thyroid adenoma	226.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 57-year-old male certified diver had 16 lifetime dives. He made a shore entry into a lake with his wife standing by on the beach. The water temperature was approximately 38 degrees F. Twenty minutes into the dive, the decedent's wife spotted the diver unconscious and floating near shore. She performed CPR and called for help, but the diver was pronounced dead upon arrival at a local hospital. After an autopsy was performed, the medical examiner ruled the death as a "dry drowning." There was no mention of any evidence of pulmonary barotrauma or gas embolism in the report, but organs were harvested for transplant prior to the post-mortem exam. The dive computer indicated that the decedent had ascended rapidly.

DAN RECORD NO: 4597 **AGE:** 35 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Insufficient air	E913.2
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Partial paralysis	344.1
Previous severe DCS with residual	993.3

Autopsy (Y/N): Y Findings available (Y/N): Y

This 35-year-old male was a very experienced diver who made a habit of using every bit of air in his tank prior to completing his dives. Five years previously he suffered a severe case of spinal cord decompression sickness and had

residual partial paralysis, which did not seem to affect his movement in the water. The diver made a night dive to 115 fsw with another diver, but they agreed to go their separate ways once entering the water. The decedent did not return from the dive and his body, along with an empty tank, was recovered 16 hours later. The autopsy findings were consistent with drowning.

DAN RECORD NO: 6097 **AGE:** 53 **SEX:** M **DIVER CAT:** R

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

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

Coronary atherosclerosis, severe	414.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 53-year-old male was a certified diver with only 16 lifetime dives. He made a series of dives with short surface intervals apparently without changing his tank between dives. At the end of the last dive he was noted to be struggling on the surface and unable to swim back to the boat. The diver then lost consciousness and, despite being rescued by other divers in the group, resuscitation efforts were unsuccessful. The decedent's tank was found to be completely empty. The autopsy was signed out with drowning as the cause of death. The decedent also had severe coronary artery disease as evidence by a 80 percent narrowing of the left anterior descending coronary artery.

DAN RECORD NO: 6397 **AGE:** 35 **SEX:** F **DIVER CAT:** R

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

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

Toxicology positive for benzodiazepine	E934.4

Autopsy (Y/N): Y Findings available (Y/N): Y

This 35-year-old female diver had advanced open-water certification and belonged to a volunteer water rescue team. She was making a recreational dive with another member of the team in a local river. The divers made a shore entry and spent 58 minutes at a maximum depth of 42 feet. The decedent was experiencing dry suit problems and was over-weighted. During ascent, the divers became separated and the buddy searched for the missing diver without success. Her body was recovered one week later.

DAN RECORD NO: 6997 **AGE:** 26 **SEX:** M **DIVER CAT:** R

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

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

Panic	308
Coronary atherosclerosis, mild	414.0
Tobacco abuse	305.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 26-year-old male was recently certified and had six lifetime dives. He made an initial dive to 30 feet in a lake along with three other divers. The second dive was planned to be to 100 feet, but the decedent began the dive with only 1500 psi of air. After a period of time on the bottom, the decedent surfaced to remove his hood. He rejoined the group of divers, but then became separated from them near a steep ledge. The diver was seen sinking toward the bottom and struggled when another diver attempted to assist him. The body was recovered 24 hours later. An autopsy revealed changes consistent with drowning. Bubbles were also present in the coronary and cerebral vessels. An AGE cannot be ruled out, but it would have had to occur earlier in the dive when the decedent briefly surfaced.

Drowning / Accident

DAN RECORD NO: 974 **AGE:** 42 **SEX:** M **DIVER CAT:** UNK

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 42-year-old male made an initial dive to 40 fsw for 45 minutes followed by a second dive to 81 fsw for 18 minutes. No information regarding the diver's level of certification and experience is known. The decedent made the second dive without a buddy and was found unconscious on the bottom by another diver. The autopsy showed no evidence of cardiovascular disease or pulmonary barotrauma. The event that resulted in this diver's drowning was not witnessed.

DAN RECORD NO: 1397 **AGE:** 38 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

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

Asthma	493.9

Significant incidental findings:

Fatty Liver	571.8

Autopsy (Y/N): Y Findings available (Y/N): Y

This was a 38-year-old woman who had made less than 12 lifetime dives and also had a history of asthma. She was noticed to use inhalers prior to entering the water to dive. She made a shore entry into a lake with a dive instructor and a student whom the instructor was teaching. Visibility was poor and the decedent became separated from the other two divers on the way to a teaching platform. She was found on the bottom with her regulator out of her mouth. Resuscitation efforts were unsuccessful and the autopsy findings were consistent with drowning.

DAN RECORD NO: 4497 **AGE:** 60 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

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

Contusions and lacerations, multiple	959.8
Coronary atherosclerosis, mild	414.0
Fatty liver	571.8

Autopsy (Y/N): Y Findings available (Y/N): Y

This 60-year-old female had made 10 lifetime dives prior to making this dive with a large group. The decedent entered the water from a boat anchored close to shore and returned once to the boat to get additional weights. After the decedent became separated from the group, she was seen near the rocky shore, apparently struggling on the surface in the strong surf and large swells. Despite receiving assistance from several people who swam out to her from shore, the diver succumbed to the rough conditions and could not be resuscitated. The autopsy showed evidence of external trauma and findings consistent with drowning.

DAN RECORD NO: 4797 **AGE:** 50 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

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

Coronary atherosclerosis, severe	414.0
Left ventricular hypertrophy	429.3
Myocardial infarcts, remote	412.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 50-year-old male had advanced open water certification with 30 lifetime dives. There are few details available about this mishap, but the decedent became separated from his buddy while on the bottom and the body was recovered

a period of time after that. The autopsy disclosed changes consistent with drowning as well as extensive cardiovascular disease. It cannot be determined with certainty how great a role the heart disease played in this diver's death.

DAN RECORD NO: 4897 **AGE:** 57 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Coronary atherosclerosis, mild	414.0
Left ventricular hypertrophy	429.3
Obesity	278.0
Fatty liver	571.8
Significant incidental findings:	
Prostatic hypertrophy	600.0
Cholelithiasis	574.2

Autopsy (Y/N): Y Findings available (Y/N): Y

This 57-year-old male certified diver made an annual dive trip for the past 10 years, but seldom made any dives between these trips. He usually used up his air before the other divers in the group and it was typical for him to ascend several minutes before his buddies. After a 20-minute dive to 55 fsw, the decedent signaled to the other divers that he was going to ascend. He reportedly ascended to 10-15 fsw, stopped, and then appeared to continue toward the surface. He was next seen floating on the surface without his regulator in his mouth. Resuscitation procedures were unsuccessful. The autopsy report lists the cause of death as drowning, though a precipitating cardiac event cannot be ruled out.

DAN RECORD NO: 5297 **AGE:** 43 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Left ventricular hypertrophy	429.3
Coronary atherosclerosis, mild	414.0
Obesity	278.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 43-year-old male certified diver made a shore entry, possibly without a buddy. He was reported to be missing and his body was found by a search team two hours later. Nothing is known about the decedent's dive profile or experience level. The autopsy findings were consistent with drowning, but a cardiac event cannot be ruled out. The decedent had also been taking antibiotics for an upper respiratory tract infection during the week prior to the dive.

DAN RECORD NO: 5797 **AGE:** 38 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Hashimoto's thyroiditis	245.2
Myxoid mitral valve	424.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 38-year-old male certified diver had eight lifetime dives. He and two dive buddies made a shore entry, but his buddies were having buoyancy problems and stayed in shallow water. The decedent went off on his own and was later seen on the surface, waving for assistance. The stricken diver was brought back to the beach, but resuscitation efforts were unsuccessful. An examination of the decedent's equipment revealed that he was markedly over-weighted and low on air. There was also mention of a possible asthma history, but that could not be substantiated.

DAN RECORD NO: 5897 **AGE:** 46 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

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

Panic	308.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 46-year-old male had been certified one year when he made an ocean dive using a shore entry through the rough surf. His dive buddies were many yards ahead of him as the three divers entered the water. The decedent called for help while still in the surf zone and one of the other divers swam to his aid. By the time the dive buddy arrived the decedent was struggling to keep his head above water. He rapidly became unconscious and was brought to shore where resuscitation efforts were unsuccessful. The autopsy findings were consistent with drowning and there was no evidence of significant natural disease processes.

DAN RECORD NO: 6297 **AGE:** 33 **SEX:** M **DIVER CAT:** U

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 33-year-old male was not a certified diver, but made a shore entry dive in an attempt to free a shrimp net that had become tangled in a drainage pipe. The maximum depth in the area was 30 fsw. Within 30 minutes of the time the diver entered the water, his father saw him floating on the surface off shore. The decedent's father swam out and brought him back to shore where resuscitation efforts were unsuccessful. An autopsy revealed only findings consistent with drowning.

DAN RECORD NO: 6497 **AGE:** 23 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

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

Diphenhydramine present	E933.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 23-year-old male certified diver was an experienced but infrequent diver. He made a shore entry dive with two buddies in a rough surf zone. During ascent, the diver became separated from his buddies in the strong surge. The decedent's buddies thought that he was ahead of them and did not realize the diver was missing until they were back on the shore. The diver's body was recovered the next day. An autopsy listed drowning as the cause of death and described several skin abrasions that the pathologist felt occurred after death.

DAN RECORD NO: 7797 **AGE:** 42 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

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

Coronary atherosclerosis	414.0
Left ventricular hypertrophy	429.3
Obesity	278.0
Hypertension	401.9

Autopsy (Y/N): Y Findings available (Y/N): Y

This 42-year-old male diver with advanced certification was preparing to enter a freshwater spring for a dive with one other person. As the decedent neared the entrance to the spring, his buddy heard him call out before he fell into the water. The buddy came to the decedent's aid, but he had already slipped below the surface and had to be pulled from the spring. An investigation revealed that the decedent likely fell into the spring prior to having his equipment ready for use.

DAN RECORD NO: 7897 **AGE:** 47 **SEX:** F **DIVER CAT:** S

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 47-year-old female was in a scuba familiarization class and had no other formal dive training. She was initially uncomfortable with the idea of submerging, but finally agreed to descend. The diver became separated from the group in 10 feet of water and was found unconscious on the bottom 20 minutes later. The autopsy findings were consistent with drowning.

DAN RECORD NO: 8097 **AGE:** 39 **SEX:** M **DIVER CAT:** UNK

Cause of Death	**ICD-9-CM**
Immediate: Anoxic encephalopathy	348.1
Due to: Near drowning	994.1
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Left ventricular hypertrophy	429.3
Obesity	278.0

Autopsy (Y/N): Y Findings available (Y/N): Y

There is no dive history available on the death of this 39-year-old male It is also not certain what his level of certification was, or if he had any formal certification. The decedent was with three other divers and apparently never descended. He struggled on the surface and was brought back to shore where he went into cardiac arrest. Resuscitation procedures were unsuccessful, and autopsy findings were consistent with drowning.

Drowning / Entrapment

DAN RECORD NO: 5997 **AGE:** 34 **SEX:** M **DIVER CAT:** T

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Entangled, wire	E918
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Coronary atherosclerosis	414
Left ventricular hypertrophy	429.3
Gastric ulcers	531.9

Autopsy (Y/N): Y Findings available (Y/N): Y

This 34-year-old, experienced, certified master diver made a dive in a freshwater lake to explore a popular wreck without a buddy. He planned on penetrating the wreck and brought along guide wires. When the diver became entangled in wire, he removed his diving gear in an unsuccessful attempt to free himself. The body and equipment were recovered separately.

DAN RECORD NO: 6897 **AGE:** 34 **SEX:** M **DIVER CAT:** S

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Entangled, rope	E918.5
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Depression, on antidepressant medications	296.2

Autopsy (Y/N): Y Findings available (Y/N): Y

This 34-year-old male was making his open-water checkout dives for initial certification. He initially began the course a year earlier and had made two uneventful dives the previous day. After a dive to 49 feet for 33 minutes, the decedent and his buddy began their ascent. During the ascent, the two divers became separated, and the decedent's buddy went back down to look for him. The decedent was found unconscious with his regulator entangled in the ascent line. Resuscitation attempts were unsuccessful. The autopsy findings were compatible with drowning. The decedent reportedly was taking several prescription medications while being treated for depression.

Death While Diving – Carbon Monoxide Poisoning

Carbon monoxide is a tasteless, colorless, odorless gas produced by the incomplete combustion of hydrocarbons. Carbon monoxide binds tightly to hemoglobin in red blood cells, effectively depriving tissue from oxygen. Two diving fatalities in 1997 had carbon monoxide poisoning as a contributing factor to the cause of death. Fortunately, this is an uncommon occurrence, but the problem of contaminated breathing gas may actually be under-recognized. Divers need to obtain their gas from a reputable source and dive shops need to ensure the purity of the breathing gas provided to divers.

DAN RECORD NO: 2397 **AGE:** 60 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Carbon monoxide intoxication	E868.9
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Coronary atherosclerosis, mild	414.0

Autopsy (Y/N): Y Findings available (Y/N): Y

This 60-year-old male had made fewer than 20 lifetime dives and was under instruction for high-altitude diving. During the first dive of the day, the decedent had equipment and buoyancy problems and he made a rapid ascent. The second dive was uneventful, but during the third dive the decedent descended and was next seen floating on the surface without his weight belt. He rapidly submerged again and the body was not recovered until two hours later. The post-mortem carboxyhemoglobin level was only 10 percent, but the analysis of the air remaining in the decedent's tank showed a carbon monoxide content of 537 ppm.

DAN RECORD NO: 7497 **AGE:** 42 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Carbon monoxide intoxication	E868.9
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Left ventricular hypertrophy	429.3
Coronary atherosclerosis	414.0
Chronic obstructive pulmonary disease	496.0
Toxicology positive for cannabinoids	E980.3

Autopsy (Y/N): Y Findings available (Y/N): Y

This 42-year-old experienced diver was making his second dive of the day when he lost consciousness on the bottom. Other divers in the group came to his aid and brought him to the surface, but he could not be resuscitated. Another diver in the group aborted her dive after an "O" ring failure. She complained of a headache and tingling in her fingers after getting out of the water. Subsequent evaluation of the tanks showed elevated carbon monoxide levels in several tanks, including the decedent's and the one used by the diver with a headache. A post-mortem carboxyhemoglobin level performed on the decedent was 32 percent. All affected tanks were filled at the same dive shop and an investigation revealed a malfunctioning compressor as the source of the carbon monoxide.

Death While Diving – Miscellaneous

DAN RECORD NO: 197 **AGE:** 39 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Closed head injury	854.0
Due to: Struck by boat	E838.5
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Cocaine and metabolites on toxicology	E980.4
Tobacco abuse	05.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 39-year-old male had made 30 lifetime dives, but none in the past three years. He entered the water along with his girlfriend, but when she did not descend with him he returned to the surface. The decedent's girlfriend panicked and required assistance from the boat crew. After getting the panicked diver into the boat, the crew did not see the decedent on the surface and they assumed that he had descended to join the group. The decedent's body was located nearly four hours later. The autopsy revealed evidence of blunt trauma to the head, presumedly caused by contact with the boat in rough seas.

DAN RECORD NO: 3597 **AGE:** 26 SEX: M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Open head injury	854.1
Due to: Struck by boat	E838.5
Due to: Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): Y

This 26-year-old male was an experienced and frequent diver. He made a short, shallow dive, but surfaced far from his dive flag. As the diver hit the surface, a powerboat struck him and caused severe injuries. He was pronounced dead at a local hospital.

DAN RECORD NO: 3697 **AGE:** 71 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Intracranial injury, open	854.1
Due to: Struck by boat	E838.5
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Multiple trauma	959.8
Tobacco abuse	305.1
Obesity	278.0
Fatty Liver	571.8
Significant incidental findings:	
Surgically absent left kidney	P55.51

Autopsy (Y/N): Y Findings available (Y/N): Y

This 71-year-old female certified diver had a fair amount of experience, but had not been diving during the previous year. As she was completing her second dive of the day, the decedent ascended directly into the propeller of the dive boat. The boat operator was moving around to pick up divers and the boat was put into gear at that same moment. Witnesses wondered if an impairing medical problem could have caused the diver to ascend into the propeller. The decedent had no known significant pre-existing medical problems.

DAN RECORD NO: 7197 **AGE:** 26 **SEX:** M **DIVER CAT:** UNK

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Closed head trauma	854.0
Due to: Scuba diving	E910.1

Other significant conditions possibly contributing to death but not resulting in the underlying cause:
Panic 308.0
Autopsy (Y/N): Y Findings available (Y/N): Y
This 26-year-old male made a shore entry dive in rough surf. At the completion of the dive, the decedent and his dive buddy exited the water by climbing up a rocky ledge. A large wave pushed the diver up against the rocks and swept him off of the ledge. The autopsy revealed evidence of head trauma and changes consistent with drowning.

Autopsied Cases – Report Not Available

In general, DAN has an excellent relationship with medical examiner offices, and their cooperation is essential in making these case histories available to the public. DAN receives timely autopsy and accident reports on a majority of the diving fatalities. In every case, confidentiality regarding names and specific locations is maintained. There were nine diving fatalities reported in 1997 where an autopsy was performed but the results were not made available to DAN. Several of these cases occurred outside of the United States, but the increasing litigious environment surrounding diving fatalities has resulted in less information being made available on some U.S. fatalities.

Air Embolism

DAN RECORD NO: 3497 **AGE:** 42 **SEX:** M **DIVER CAT:** R
Cause of Death **ICD-9-CM**
Immediate: Air embolism 958.0
Due to: Scuba diving E910.1
Autopsy (Y/N): Y Findings available (Y/N): N
This 42-year-old male had advanced open-water certification. He made a dive to 100 feet for 13 minutes in a high-altitude freshwater lake. The decedent's buddy had regulator problems and signaled that he was going to ascend. The buddy remembered seeing the decedent ascending with him until they reached 60 feet where they became separated. After his partner did not surface, the dive buddy went back down to look for him. The body was located seven hours later after an extensive search. The decedent's buddy required treatment for decompression sickness. An autopsy report was not released, but the cause of death was reported to be an AGE.

Cardiovascular Disease

DAN RECORD NO: 2997 **AGE:** 67 **SEX:** M **DIVER CAT:** R
Cause of Death **ICD-9-CM**
Immediate: Acute myocardial infarction 410.9
Due to: Coronary atherosclerosis 414.0
Other significant conditions possibly contributing to death but not resulting in the underlying cause:
Scuba diving E910.1
Autopsy (Y/N): Y Findings available (Y/N): N
This 67-year-old male was an instructor with several hundred previous dives logged. Five minutes into the dive, witnesses said the decedent's regulator dropped from his mouth. Others divers rendered aid, including performing CPR, but he was pronounced dead at the local recompression chamber. The decedent had a history of aortic stenosis, ventricular tachycardia, depression and other health problems. A physician had recommended a treadmill test to check heart function, but the decedent elected not to follow the advice.

DAN RECORD NO: 6197 **AGE:** 36 **SEX:** M **DIVER CAT:** R
Cause of Death **ICD-9-CM**
Immediate: Cardiac dysrhythmia 427.9
Due to: Left ventricular hypertrophy 429.3
Due to: Hypertension 401.9
Other significant conditions possibly contributing to death but not resulting in the underlying cause:
Sarcoidosis 517.8
Bronchitis 490.0
Obesity 278.0
Scuba diving E910.1

Autopsy (Y/N): Y Findings available (Y/N): N

This very experienced divemaster made a dive to 50 fsw for 35 minutes in very cold water. He was reported to be somewhat agitated before the dive. At the end of the dive, he and his buddy briefly became separated. He was seen to collapse after making a shore exit from the water. Cardiopulmonary resuscitation was initiated, and the diver was transferred to a local hospital where he was pronounced dead. An autopsy was performed, but the report was not made available.

DAN RECORD NO: 6697 **AGE:** 51 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Acute myocardial infarction	410.9
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): N

This 51-year-old female with moderate diving experience was in a poor state of physical conditioning. She was making her second dive of the day when she became incapacitated on the bottom. The decedent was brought to shore where resuscitation efforts were unsuccessful. The autopsy report is unavailable and there are few details known about this case. The death certificate lists the cause of death as drowning secondary to an acute myocardial infarction.

Drowning / Accident

DAN RECORD NO: 297 **AGE:** 28 **SEX:** M **DIVER CAT:** U

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): N

This 28-year-old male had no formal dive training and was making his first-ever lifetime dives as part of a group hunting for lobster. The first dive was uneventful, but at the end of the second dive the decedent stayed behind after his buddy signaled to ascend. The other divers did not feel that they had enough air to return to the bottom, so they called for assistance. The body was recovered after a five-hour search. An autopsy report has not been released.

DAN RECORD NO: 4097 **AGE:** 53 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

Autopsy (Y/N): Y Findings available (Y/N): N

Little information is available about this fatality. This 53-year-old male with extensive diving experience ascended alone because of a health problem before completing a dive. The other divers found him floating face down on the surface. The decedent had apparently not been feeling well all week and he may have had a history of diabetes. The death certificate lists asphyxia due to drowning as the cause of death. A precipitating cardiac event is very likely.

DAN RECORD NO: 4397 **AGE:** 33 **SEX:** M **DIVER CAT:** R/T

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:	
Shark bites	E906.3
Nitrogen narcosis	293.0

Autopsy (Y/N): Y Findings available (Y/N): N

This very experienced dive instructor was set on breaking the world record for deep diving using air. He and another diver made an earlier dive to 30 fsw for 45 minutes. They followed that with a dive to a depth in excess of 290 fsw. This diver's body was found a day later and the dive buddy's body was never recovered. The forensic pathologist and another investigator are fairly certain that one of the traumatic injuries was a shark bite that occurred prior to death. It is often very difficult to distinguish antemortem and post-mortem animal bites on bodies that have been in water for any length of time.

Drowning / Insufficient Air

DAN RECORD NO: 997 **AGE:** 39 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Insufficient air	913.2
Due to: Scuba diving	E910.1

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

Obesity	278.0

Autopsy (Y/N): Y Findings available (Y/N): N

This 39-year-old male was open-water certified, but only had seven lifetime dives. After free-diving for abalone in the morning, the decedent planned an afternoon scuba dive with his sister and brother-in-law. The group was down to 60 fsw for 20 minutes when the decedent became separated from the other two divers. A thorough search was performed, but the body was not recovered until 12 days later. When his body was recovered, the decedent still had his 55 pound weight belt on and his tank was noted to be empty. The autopsy report is unavailable, but the death certificate reports drowning as the cause of death. A cardiac event cannot be excluded, and the empty tank makes air embolism also a possibility.

DAN RECORD NO: 5397 **AGE:** 21 **SEX:** M **DIVER CAT:** R

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

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

Panic	308.0

Autopsy (Y/N): Y Findings available (Y/N): N

This 21-year-old male had been certified one month and had made six lifetime dives. He and a more experienced diver made a night dive to 95 fsw in cold water. The decedent had forgotten his fins so each diver wore only one fin. When both divers became low on air, they decided to surface, but the decedent had difficulty getting off the bottom. His buddy tried to offer assistance, but the decedent was combative and the buddy had to surface rapidly without a regulator in his mouth. The dive buddy was treated for decompression illness and decedent's body was not recovered until 30 days later. The autopsy report was not released, but it seems that the deceased diver was also severely overweighted.

Fatality Reports – Autopsy Not Performed

The complete investigation of a scuba-diving fatality requires an autopsy. Scuba deaths may be considered sudden deaths because they are unexpected and occur within a short time of the causal event. The factors leading to a fatal outcome and the manner of death are often clarified or confirmed by the findings of a post-mortem examination. At least initially, all diving-related fatalities should be considered non-natural deaths. Only a complete investigation, including the performance of a thorough post-mortem examination, will reveal whether the death was natural or accidental.

Diving deaths cause tremendous psychological trauma to families and survivors. They may receive some solace and a better understanding of the event with full disclosure of the details of the injury or illness. It is very important to answer the family's questions fully, and, to the best of the investigator's knowledge, making it clear how and why the diver died.

There are legal reasons for performing an autopsy. Frequently, life insurance benefits are determined by the autopsy findings, such as the double indemnity provision with many policies in cases of accidental death.

Scuba diving deaths are occasionally the basis for a lawsuit. Additionally, the victim is often young and otherwise healthy. A thorough autopsy provides evidence of fact and medical opinion that will be introduced into legal proceedings. The autopsy report must be carefully written in order to avoid the suggestion of error by anyone, when, in fact, no error is known to exist.

Air Embolism

DAN RECORD NO: 3097 **AGE:** 15 **SEX:** M **DIVER CAT:** S

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

Autopsy (Y/N): N Findings available (Y/N): N

This 15-year-old male was making his first lifetime dive as part of an initial open water training course. During free ascent training, he came to the surface from 35 fsw with his regulator out of his mouth. The decedent collapsed shortly after giving an "OK sign" on the surface. Resuscitation procedures were initiated and he was ultimately transferred to a hospital where a recompression chamber was available. An attempt was made to treat the boy on a USN TT6, but his condition did not improve and he was pronounced dead prior to completion of the treatment table. An autopsy was not performed.

Drowning / Accident

DAN RECORD NO: 2297 **AGE:** 43 **SEX:** F **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

Autopsy (Y/N): N Findings available (Y/N): N

This 43-year-old female had received her initial open-water certification two weeks earlier and was making her first night dive. It is unclear what problems the diver may have had on the bottom, but the dive was aborted after only six minutes. The decedent's regulator was knocked out of her mouth during ascent and she lost consciousness. Resuscitation procedures were unsuccessful. An autopsy was not performed and the cause of death was reported as drowning.

Death While Diving – Unknown Cause

DAN RECORD NO: 897 **AGE:** 63 SEX: M DIVER CAT: R

Cause of Death	**ICD-9-CM**
Immediate: Death, unspecified cause	798.2
Due to: Scuba diving	E910.1

Autopsy (Y/N): N Findings available (Y/N): N

This 63-year-old male certified diver entered the water from shore without a dive buddy. He was later seen floating on the surface and could not be resuscitated after being brought to shore. An autopsy was not performed; local authorities presumed the death to be due to cardiovascular disease.

DAN RECORD NO: 2097 **AGE:** 68 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Death, unspecified cause	798.2
Due to: Scuba diving	E910.1

Autopsy (Y/N): N Findings available (Y/N): N

This 68-year-old male was completing a decompression dive to 180 fsw on a wreck when he experienced a problem during one of his decompression stops. The decedent and his buddy became separated so the exact event was not witnessed; it is believed that he lost consciousness while at one of the decompression stops. The dive buddy found the decedent 30 minutes later and emergency personnel did not arrive on the scene for an additional 40 minutes. The most likely cause of death in this setting is a coronary event, but there is not an autopsy and the exact details surrounding the fatality are scant.

Unknown if Autopsy Performed

Cardiovascular Disease

DAN RECORD NO: 1297 **AGE:** 54 **SEX:** M **DIVER CAT:** R

Cause of Death	**ICD-9-CM**
Immediate: Cardiac dysrhythmia	427.9
Due to: Coronary atherosclerosis	414.0

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

Tobacco abuse	305.1
Scuba diving	E910.1

Autopsy (Y/N): UNK Findings available (Y/N): N

This 54-year-old male had been certified for three years and was a moderately experienced diver. After entering the water and during the pre-dive surface swim, the decedent became unconscious and started to drift away from his buddy. The stricken diver was brought back to the boat where CPR was initiated, but oxygen was not available. He was pronounced dead at the closest hospital. If an autopsy was performed, the report was not made available.

Drowning / Accident

DAN RECORD NO: 1197 **AGE:** 17 **SEX:** M **DIVER CAT:** U

Cause of Death	**ICD-9-CM**
Immediate: Drowning	994.1
Due to: Scuba diving	E910.1

Autopsy (Y/N): UNK Findings available (Y/N): N

This 17-year-old male had no formal dive training when he made a shore entry dive, alone, using borrowed equipment. His friends, who were certified divers, waited back on shore. Rescue divers recovered the decedent's body. No information regarding an autopsy or police investigation is available.

Drowning / Insufficient Air

DAN RECORD NO: 5097 **AGE:** 25 **SEX:** M **DIVER CAT:** UNK

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

Autopsy (Y/N): UNK Findings available (Y/N): N

This 25-year-old was the younger of two brothers involved in a double diving fatality. Both men went down to at least 115 fsw and their bodies were not recovered until the next day. Little information is available.

DAN RECORD NO: 5197 **AGE:** 27 **SEX:** M **DIVER CAT:** UNK

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

Autopsy (Y/N): UNK Findings available (Y/N): N

This 27-year-old male and his 25-year-old brother made a dive to at least 115 fsw while two other people waited back in the boat. The divers were not seen again until the bodies were recovered the next day. Few details are available on this mishap.

Bodies Not Recovered

Each year there are cases where diving fatalities occur, but a body is never recovered. There were five such cases in 1997. In a few instances, the circumstances surrounding the mishap are known. Most often, the final events of the dive are not known.

DAN RECORD NO: 5697 **AGE:** 42 **SEX:** M **DIVER CAT:** UNK
Cause of Death **ICD-9-CM**
Immediate: Death, unspecified cause (body not recovered) 799.9
Autopsy (Y/N): N/A Findings available (Y/N): N
This 42-year-old male made a shore entry dive along with another diver (2797). The two divers were never seen again, although their car remained parked on the beach and some of the dive equipment was recovered. No other information is available.

DAN RECORD NO: 2797 **AGE:** 31 **SEX:** M **DIVER CAT:** UNK
Cause of Death **ICD-9-CM**
Immediate: Death, unspecified cause (body not recovered) 799.9
Autopsy (Y/N): N/A Findings available (Y/N): N
This 31-year-old male was the dive buddy of a previous case (5697). The circumstances surrounding this mishap, the diving experience of the decedent's, and whether this can even be classified as a diving fatality are all unknown.

DAN RECORD NO: 3897 **AGE:** 32 **SEX:** F **DIVER CAT:** R/T
Cause of Death **ICD-9-CM**
Immediate: Death, unspecified cause (body not recovered) 799.9
Due to: Scuba diving E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:
Nitrogen narcosis 293.0
Autopsy (Y/N): N/A Findings available (Y/N): N
This 32-year-old female with divemaster certification had more than 500 lifetime dives. She was treated for an arterial gas embolism in 1995. The decedent entered the water with a local divemaster to perform a very deep dive on air. The local divemaster surfaced without the decedent, and a body was never recovered.

DAN RECORD NO: 3997 **AGE:** 28 **SEX:** M **DIVER CAT:** R/T
Cause of Death **ICD-9-CM**
Immediate: Death, unspecified cause (body not recovered) 799.9
Due to: Scuba diving E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:
Nitrogen narcosis 293.0
Autopsy (Y/N): N/A Findings available (Y/N): N
This 28-year-old male was an experienced divemaster who decided to help another diver challenge the record for deep diving on air. After making an initial dive to 30 fsw for 45 minutes, the two divers descended past 290 fsw. His dive buddy's body was recovered a day later; the body of this diver was never recovered. One can only speculate as to the cause of death, but most likely nitrogen narcosis resulted in drowning.

DAN RECORD NO: 4197 **AGE:** 25 **SEX:** M **DIVER CAT:** R
Cause of Death **ICD-9-CM**
Immediate: Death, unspecified cause, (body not recovered) 799.9
Due to: Scuba diving E910.1
Other significant conditions possibly contributing to death but not resulting in the underlying cause:
Nitrogen narcosis 293.0
Autopsy (Y/N): N/A Findings available (Y/N): N
This 25-year-old dive instructor was distraught over a breakup with his girlfriend. Witnesses recall him stating that he would go to 350 fsw on one tank and bring a computer along to prove the dive profile. He also may have been using alcohol at the time. Local authorities presume that the decedent made a deep dive as predicted. A body was never recovered.

Unknown Cause of Death

In these cases, not enough information was available to even speculate about the cause of death. Many of these cases involved U.S. citizens diving abroad, and the details of their deaths, if in fact it actually occurred in the water, were unknown.

DAN RECORD NO: 1997 **AGE:** 30 **SEX:** M **DIVER CAT:** UNK

Cause of Death **ICD-9-CM**

Immediate: Death, unspecified cause 798.2

Due to: Scuba diving E910.1

Autopsy (Y/N): UNK Findings available (Y/N): N

This 30-year-old male was illegally using scuba equipment to gather abalone. He had his tank and regulator tethered to one wrist with an abalone iron on the other wrist. The circumstances of his death, his dive certification, and an autopsy report, if an autopsy was performed, are unavailable.

DAN RECORD NO: 2197 **AGE:** 65 **SEX:** F **DIVER CAT:** R

Cause of Death **ICD-9-CM**

Immediate: Death, unspecified cause 798.2

Due to: Scuba diving E910.1

Autopsy (Y/N): UNK Findings available (Y/N): N

This 65-year-old female certified diver had been diving for six years and had made greater than 100 dives. She made a dive to 90 fsw in a large group and her buddy noted she was having a problem while on the bottom. The decedent had lost consciousness and was brought to the surface where resuscitation efforts were unsuccessful. No other information is available on this case and the findings of an autopsy, if one was performed, are unavailable. The most likely cause of death in this scenario would be a cardiac event.

DAN RECORD NO: 8197 **AGE:** 53 **SEX:** M **DIVER CAT:** R

Cause of Death **ICD-9-CM**

Immediate: Death, unspecified cause 798.2

Due to: Scuba diving E910.1

Autopsy (Y/N): UNK Findings available (Y/N): N

There is little information available on the death of this 53-year-old male. He may have had a history of cardiac problems. No information regarding the dive or the presumed cause of death is available from local authorities.

Summary

DAN presents these fatality reports each year to be used as an instructional device for all divers, from novice to seasoned veteran. Nearly every fatal diving scenario has a take home message or lesson to be learned that hopefully will prevent future similar outcomes. A majority, though not all, of these cases involves an error in judgment or a violation of accepted safe diving practices. As divers, we are responsible for our own actions and must ensure that we are:

- Adequately trained for the type of diving planned, including advanced training for more challenging types of diving;
- Mentally and physically prepared to make the dive with enough physical reserve and training to handle changing diving conditions and emergencies;
- Well-acquainted with dive equipment, ensuring the equipment is well-maintained.

Most diving fatalities are accidents that are preventable. Important contributing factors to a diving fatality include: dive experience and training, pre-existing health problems, level of physical fitness, and the influence of alcohol and other drugs. Conservative diving habits for novice divers should be encouraged and advanced training prior to engaging in more challenging types of diving is essential.

Notes

1. International Classification of Diseases, 9th Revision, Clinical Modification, fourth edition, U.S. Department of Health and Human Services, Health Care Financing Administration.
2. Kindwall, EP and Pellegrini, JP. Autopsy Protocol for Victims of Scuba Diving Accidents, *1992 Report on Diving Accidents and Fatalities*, Divers Alert Network: Durham, NC, 1994.
3. Di Maio, DJ and Di Maio, VJ. *Forensic Pathology*, CRC Press: Boca Raton, 1993
4. Caruso, JL, et al. Fatalities Related to Cardiovascular Disease in the Recreational Diving Population. Undersea and Hyperbaric Medicine, 24 (supp): 26, 1997.
5. National Center for Health Statistics, U.S. Public Health Service, DHHS.
6. Caruso, JL, et al. Recreational Diving Fatalities in the United States, 1990-1994: Patterns and Trends. Undersea and Hyperbaric Medicine, 23 (supp): 60-61, 1996.
7. Caruso, JL, et al. Inexperience Kills: The Relationship Between Lack of Diving Experience and Fatal Diving Mishaps. Undersea and Hyperbaric Medicine, 25(supp): 32, 1998.
8. Dovenbarger, JD, ed. *1993 Report on Diving Accidents and Fatalities*, Divers Alert Network: Durham, NC, 1995, p. 34.

The views expressed in this article are those of the author and do not reflect the official policy or position of the Department of the Navy, Department of Defense or the U.S. Government.

Appendix B

Autopsy Protocol for Recreational Scuba Diving Fatalities

The *1992 Report on Diving Accidents and Fatalities** included an autopsy protocol written by Doctors Eric Kindwall and Jorge Pellegrini [1]. Several aspects of that protocol have been incorporated in the following section on performing and interpreting a post-mortem examination on a diving fatality victim.

Since most pathologists and autopsy technicians rarely perform an autopsy on someone who died while scuba diving, few medical examiners' offices will have significant experience in performing appropriate post-mortem examinations in that setting. The following is a guideline which can be followed with the understanding that some of the recommended procedures will be impractical and may only take place in a facility with significant laboratory resources available.

The medical examiner must put together all of the available information, including the autopsy findings, prior to determining the cause of death in a diving fatality. If the pathologist performing the autopsy is unfamiliar with diving physiology, consultation should be obtained to assist in the interpretation of the findings.

History

This is absolutely the most important part of the evaluation of a recreational diving fatality. Ideally, one should obtain significant past medical history with a focus especially on cardiovascular disease, seizure disorder, diabetes, asthma and chronic obstructive pulmonary disease. Medications taken on a regular basis as well as on the day of the dive should be recorded, and information regarding how the diver felt prior to the dive should be obtained. Any history of drug or alcohol use must also be noted. The dive history is extremely important. If possible, the investigator should find out the diver's experience and certification level. The most important part of the history will be the specific events related to the dive itself. The dive profile (depth, bottom time) is an essential piece of information, and if the diver was not diving alone (solo diving is not recommended), eyewitness accounts will be invaluable.

Questions to be asked include:

- When did the diver begin to have a problem (pre-dive, descent, bottom, ascent, post-dive)?
- Did the diver ascend rapidly (a factor in air embolism and pulmonary barotrauma)?
- Was there a history of entrapment, entanglement, or physical trauma?
- If resuscitation was attempted, what was done and how did the diver respond?
- Was there any obvious equipment malfunction? (See note at the end of this section.)

External Examination and Preparation

- A thorough external examination including a search for signs of trauma, animal bites, or envenomation should be carried out. Palpate the area between the clavicles and the angles of the jaw for evidence of subcutaneous emphysema. X-rays of the head, neck, thorax and abdomen should be taken to look for free air.
- Modify the initial incision over the chest to make a "tent" out of the soft tissue (an "I" shaped incision) and fill this area with water. A large-bore needle can be inserted into the second intercostal spaces bilaterally; if desired, any escaping air can be captured in an inverted, water-filled, graduated cylinder for measurement and analysis. As the breastplate is removed, note any gas escaping from vessels. Excellent diagrams exist in one of the standard forensic pathology texts [2].
- The carotid arteries should be tied off immediately upon opening the chest.
- Open the pericardial sac under water and note if pneumopericardium is present. After filling the pericardial sac with water, repeat the needle insertion maneuver, this time into the right and left ventricles, with capture of any escaping gas if practical. After the mediastinum, heart and great

* *Note: The name* Report on Diving Accidents and Fatalities *was changed to* Report on Decompression illness and Diving Fatalities *with the reporting of 1995 data in the report published in 1997.*

vessels have been examined underwater for the presence of air, the water may be evacuated and a standard autopsy may be performed.

• Carefully examine the lungs for bullae, emphysematous blebs and hemorrhage.

• Note any inter-atrial or inter-ventricular septal defects. Carefully check for evidence of cardiovascular disease and any changes that would compromise cardiac function.

• Toxicology-obtain blood, urine, vitreous, bile, liver and stomach contents. Not all specimens need to be analyzed, but at least look for drugs of abuse. If an electrolyte abnormality is suspected or if the decedent is a person with diabetes, the vitreous may prove useful.

• Prior to opening the skull, tie off all of the vessels in the neck to prevent artifactual air from entering the intracranial vessels. Tie the vessels at the base of the brain once the skull is opened. Disregard bubbles in the superficial veins or venous sinuses. Examine the meningeal vessels and the superficial cortical arteries for the presence of gas. Carefully examine the circle of Willis and middle cerebral arteries for bubbles. Alternatively, the brain may be removed prior to opening the chest, if desired.

• Have an expert evaluate the dive gear. Are the tanks empty? If not, the gas should be analyzed for purity (e.g., is carbon monoxide present?). All gear should be in good working order with accurate, functioning gauges.

Possible Findings

The following anatomic findings may be seen with the clinical entities listed. Not all of the anatomic changes will be seen in each case, and the lists are certainly not exhaustive.

• **air embolism**: intra-arterial and intra-arteriolar air bubbles in the brain and meningeal vessels, petechial hemorrhages in gray and white matter, evidence of COPD (chronic obstructive pulmonary disorder) or pulmonary barotrauma (pneumothorax, pneumomediastinum, subcutaneous emphysema), signs of acute right heart failure, pneumopericardium, air in coronary and retinal arteries.

• **decompression sickness**: lesions in the white matter in the middle third of the spinal cord including stasis infarction; if there is a patent foramen ovale (or other potential right-to-left heart shunt) a paradoxical air embolism can occur due to significant venous bubbles entering the arterial circulation.

• **venomous stings or bites**: a bite or sting on any part of the body, unexplained edema on any part of the body, evidence of anaphylaxis or other severe allergic reaction (beware of post-mortem changes caused by marine life).

Interpretation

• The presence of gas in any organ or vessel after a scuba diving death is not conclusive evidence of decompression sickness or air embolism. During a long dive inert gas dissolves in the tissues and the gas will come out of solution when the body returns to surface atmospheric pressure. This, combined with post-mortem gas production, will produce bubbles in tissue and vessels. This has caused many experienced pathologists to erroneously conclude that a death occurred due to decompression sickness or air embolism.

• Intravascular bubbles, especially if present predominantly in arteries, found during an autopsy performed soon after the death occurred is highly suspicious for air embolism. The dive history will help support or refute this theory.

• Gas present only in the left ventricle or if analysis shows the gas in the left ventricle has a higher oxygen content than that present on the right side would lead the pathologist to correctly conclude that an air embolism probably occurred.

• Intravascular gas from decomposition or offgassing from the dive would have little oxygen and be made up of mostly nitrogen and carbon dioxide.

• Deeper, longer dives can cause decompression sickness and significant intravascular (mostly venous) gas. Rapid ascents and pulmonary barotrauma are associated with air embolism.

Divers Alert Network has medical personnel who are available to provide guidance in the performance and interpretation of autopsies on diving accident victims.

1. Kindwall, EP and Pellegrini, JP. Autopsy Protocol for Victims of Scuba Diving Accidents, *1992 Report on Diving Accidents and Fatalities*, Divers Alert Network: Durham, NC, 1994.

2. Spitz, WV (editor). Medicolegal Investigation of Death. pp 776-778. Charles C. Thomas: Springfield, IL, 1993.

Appendix C

Fatality Location Tables

U.S. Fatalities from 1980 to 1997 in Foreign Areas

	80-89	90-92	93-95	1996	1997	Totals
Anguilla	1					1
Antigua	1					1
Australia	2		1			3
Bahamas	19	6	14	2	2	43
Barbados	2			1		3
Bequia		1				1
Bermuda	1	1				2
Belize	4	1			1	6
British Virgin Islands	4		1		2	7
Canada	6	1				7
Caribbean Area		2				2
Cayman Islands	5	2	6	3		16
Costa Rica	1					1
Dominica		1				1
Egypt		1				1
Fiji Islands	2		1			3
French Antilles	2					2
Greece	1					1
Honduras	2	1	2			5
Italy		2				2
Jamaica		3				3
Japan	3	2	1			6
Malaysia	1					1
Martinique	1	1				2
Mexico	28	15	13	6	7	69
Micronesia		1				1
Morocco	1					1
Netherlands Antilles - Saba, Aruba, Bonaire, Curacao	2	2	5		4	13
New Caledonia	1					1
Palau		1				1
Panama		1				1
Philippines	2			1		3
Portugal	1					1
Red Sea	3					3
St. Maarten			1			1
St. Martin		1				1
St Vincent/Grenadines	4					4
Saipan	1	1				2
Saudi Arabia	2			1		3
Solomon Islands					1	1
Tahiti			2			2
Thailand	1					1
Turks & Caicos					1	1
Unknown	1					1
Totals	**105**	**47**	**47**	**14**	**18**	**231**

Fatality Location Tables

U.S. Fatalities from 1980 to 1997 by State

State	80-89	90-92	93-95	1996	1997	Totals
Alabama	2	1	2		1	6
Alaska	9	2	1	1		13
Arizona	4		1		1	6
Arkansas	8	1	5			14
California	155	39	40	11	8	253
Colorado						
Connecticut	9	1	2			12
Delaware	3	1	1			5
Florida	231	58	74	18	19	400
Georgia	11	1	1	1		14
Hawaii	54	8	11	9	4	86
Idaho	4					4
Illinois	3	1	1			5
Indiana	1	1	1			3
Iowa		2				2
Kansas						
Kentucky	1			1		2
Louisiana	5	3	3	1		12
Maine	8	5	1	2	1	17
Maryland	1		1			2
Massachusetts	32	5	12	2	2	53
Michigan	12	2	6	1	1	22
Minnesota	4	1	1			6
Mississippi	3		1		1	5
Missouri	3	5				8
Montana	2	1			1	4
Nebraska	5					5
Nevada	2	1	2	1		6
New Hampshire	4					4
New Jersey	15	11	6	1	4	37
New Mexico	4	2	2			8
New York	21	10	7	2	2	42
North Carolina	12	3	2	3	3	23
Ohio	6	2	1	1	1	11
Oklahoma	1		1	1		3
Oregon	11	2	3			16
Pennsylvania	7	10	5		1	23
Rhode Island	19	4	2	2		27
South Carolina	3		2		1	6
South Dakota		1				1
Tennessee	4	2	1			7
Texas	19	4	5	1	4	33
Utah	5	1	1		1	8
Vermont	1					1
Virginia	5		2	2	1	10
Washington	67	8	18	4	3	100
West Virginia		1	2			3
Wisconsin	10	3	5	2	2	22
Wyoming	2					2
Washington DC						
Totals	**788**	**203**	**232**	**67**	**62**	**1352**

Fatality Location Tables

U.S. Fatalities from 1980 to 1997 by U.S. Territory

U.S. Territory	80-89	90-92	93-95	1996	1997	Territory Totals
Guam			5			5
Marshall Islands			2			2
Puerto Rico	5	1		1	1	8
Virgin Islands	11	3	9	1	1	25
Totals	**16**	**4**	**16**	**2**	**2**	**40**

Appendix D

ICD-9-CM Codes for Dive-Related Incidents

36.05	Angioplasty
36.10	Coronary artery bypass graft
36.11	CABG — one vessel
36.12	CABG — two vessel
36.13	CABG — three vessel
36.14	CABG — four vessel
36.15	CABG — internal mammary artery
185.0	Malignant neoplasm — prostate
189.0	Renal cell carcinoma
245.1	Chronic thyroiditis
245.2	Chronic lymphocytic thyroiditis
250.0	Diabetes mellitus
250.4	Diabetes mellitus with glomerulosclerosis
278.0	Obesity, exogenous
293.0	(Nitrogen narcosis)
	acute delirium
293.0	Acute confusional state
296.2	Depression, on anti-depressant medication
298.0	Reactive depressive psychosis
303	Ethanol dependence syndrome
303.0	unspecified
303.1	continuous
303.2	episodic
303.3	in remission
305	non-dependent drug abuse
305.0	Alcohol abuse (acute)
305.1	Tobacco abuse
308.0	Panic state
	Acute stress reaction, emotional
336.1	Intraparenchymal hemorrhage of spinal cord
345.9	Epilepsy NOS without intractable epilepsy
347.0	Cataplexy and narcolepsy
348.1	Anoxic brain damage
	Anoxic encephalopathy
348.5	Cerebral edema
394.1	Mitral insufficiency
395.0	Aortic stenosis
398.90	Rheumatic heart disease
401.9	Hypertension
402.0	Hypertensive vascular disease (HVD)
404.0	HVD with renal involvement
410.6	True posterior wall infarction
410.9	Acute myocardial infarction
412.0	Myocardial infarction, remote
414.0	Coronary atherosclerosis
414.9	Coronary artery disease
425.4	Hypertrophic cardiomyopathy
	Primary cardiomyopathy
427.41	Ventricular fibrillation
427.9	Cardiac dysrhythmia (unspecified)
428.0	Congestive heart failure
428.1	Left heart failure (pulmonary edema)
429.1	Myocardial degeneration
429.2	Arteriosclerotic cardiovascular disease (ASCVD)
429.3	Ventricular hypertrophy (cardiomegaly)
436.0	Cerebrovascular accident (CVA)
437.0	Cerebral aneurysm
440.0	Atherosclerosis aorta
466.0	Acute bronchitis
482.9	Pneumonia
490.0	Bronchitis NOS
492.0	Emphysematous blebs
492.8	Pulmonary emphysema
493.9	Asthma (unspecified)
496.0	Chronic obstructive lung disease
508.9	Pulmonary edema due to external agent
512.0	Spontaneous pneumothorax
517.8	Sarcoidosis
518.1	Pneumomediastinum
	Interstitial emphysema, mediastinal emphysema
518.5	Acute respiratory distress syndrome (ARDS)
	Post-traumatic pulmonary insufficiency
518.8	Other pulmonary insufficiency
531.9	Stomach ulcer NOS
571.2	Cirrhosis of liver (alcoholic)
571.8	Fatty liver
	Chronic non-alcoholic liver disease
574.2	Cholelithiasis
584.5	Lower nephron nephrosis
	Acute tubular necrosis
745.5	Secundum type atrial septal defect
	Patent foramen ovale
753.1	Cystic kidney disease
780.0	Coma
780.3	Seizure disorder
782.3	Pulmonary edema
786.09	Respiratory insufficiency, distress, wheezing
786.3	Pulmonary hemorrhage
789.1	Hepatomegaly
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.)
799.0	Asphyxia (hypoxemia d/t exertion)
799.9	Death, unspecified cause
	(body not found)
81.59	Bilateral hip prosthesis
853.0	Hemorrhage, brain — traumatic
854.0	Intracranial injury (head injury) closed or not specified

ICD-9-CM Codes for Dive-Related Incidents — *Continued*

854.1 Intracranial injury, (head injury) open
860.0 Pneumothorax, tension, traumatic
958.0 Air embolism
958.7 Subcutaneous emphysema
980.0 Ethanol, toxic effect
986.0 Carbon monoxide poisoning (see E codes — "Chemical Substances")
987.8 Oxygen toxicity
993.0 Barotrauma
993.0 Barotrauma, otitic
993.1 Barotrauma, sinus
993.3 Decompression sickness
994.1 Drowning and non-fatal submersion
994.5 Exhaustion due to excess exertion
994.8 Effects of electric current
E830 Rowboat drown accident, occupant
E830.1 Powerboat drowning accident, occupant
E838.5 Struck by boat
E902.2 Rapid ascent
E906.3 Shark bites
E910.1 Accident d/t water sports activity
Recreational activity with diving equipment
E910.3 Diving for purposes other than recreation with diving equipment
Marine salvage, rescue, construction, etc.
E913.2 Insufficient air
Accidental suffocation, lack of 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

* DAN adaptation of code

Chemical Substances

E868.9 Carbon monoxide accidental effect
E952.1 Carbon monoxide suicide attempt
E934.4 Benzodiazepine
E935.2 Codeine
E935.8 Propoxyphene
E937.0 Butalbital
E939.0 Fluoxetine (Prozac)
E939.0 Nortriptyline
E941.2 Pseudoephedrine
E980.3 Cannabinoids
E980.3 Methamphetamine
E980.4 Cocaine

Toxicology

Volatiles — ethanol, methanol, acetone, isopropanol and toluene.

Amphetamines — includes amphetamine, methamphetamine, phenylpropanolamine, MDA, ephedrine, pseudoephedrine and related compounds.

Barbiturates and Sedatives — includes phenobarbital, diazepam, chlordiazepoxide, flurazepam, alprazolam, triazolam, oxazepam and metabolites.

Opiates — includes heroin metabolites, morphine, codeine, meperidine, hydromorphone, hydrocodone and related compounds.

Cyclic antidepressants — includes amitriptyline, nortriptyline, imipramine, desipramine, doxepin, chlorpromazine and other related compounds such as cyclobenzaprine, thioridazine and structurally related compounds.

Antihistamines — includes diphenhydramine, tripelennamine, chlorpheniramine and other related compounds.

Psychotropics — includes phenothiazines, cyclic antidepressants, anti-anxiety agents and other related compounds.

Organic bases — includes pentazocine, methaqualone, cocaine and metabolites, propoxyphene, strychnine, methadone, ethclorvynol, quinine, chlorinated hydrocarbons and other related compounds.

Abbreviations

d/t due to
s/p status post
w/o without
ALS Advanced life support
ARDS Adult respiratory distress syndrome
ATN Acute tubular necrosis
CAD Coronary artery disease
CABG Coronary artery bypass graft
LAD Left anterior descending coronary artery
Lcirc Circumflex coronary artery
NOS Not otherwise specified
NEC Not elsewhere classifiable
RCA Right coronary artery

Appendix E

Nitrox and Mixed-Gas Diving – 1997 Injuries Reported

There have been many advances in recreational diving since the first national training program was instituted by the YMCA in 1959. Almost everything about recreational diving and diving equipment has evolved. Even the recommended safety guidelines for recreational diving have been modified over the years to reflect current understanding and knowledge of safe diving practices. Innovations in the design of scuba regulators, buoyancy compensators, weighting systems, and the design of masks, fins and exposure suits (i.e., wet- and drysuits) have all added to the ease, comfort and, sometimes, the safety of diving.

The introduction of decompression computers revolutionized the way divers are able to perform multidepth and repetitive dives without cumbersome calculations using printed tables.

Today, a much-discussed option available to scuba for the general recreational scuba diving public is the use of gas mixtures other than compressed air, such as nitrox or mixed gas.

"Mixed gas" refers to a breathing gas that has been mixed from component gases, inert gases and oxygen. "Nitrox" refers to a mixed gas containing only nitrogen and oxygen, and the oxygen fraction may be more or less that the 21 percent found in air. "Enriched-air nitrox" (EAN) refers to nitrox mixes having an oxygen fraction higher than 21 percent, usually made by mixing oxygen with air. "Heliox" or "Oxyhelium" is a gas mixture of helium and oxygen and "trimix" usually refers to a mixture of helium, nitrogen and oxygen. In this appendix, all types of diving using a gas other than air will be referred to as mixed gas diving. Of all forms of mixed-gas diving, recreational and technical divers perform nitrox diving using EAN the most frequently. The use of mixed gas in recreational diving is controversial, because in the past, mixed gas was used solely in commercial, military, and scientific diving operations. This implied that mixed-gas diving was too complex and required much more training than the average recreational diver might receive.

All that changed in 1985, when Dick Rutkowski, of Key Largo, Fla., began the International Association of Nitrox and Technical Divers (IANTD) and began instructing recreational divers in the use of nitrox. The instructional course followed the policies and procedures developed by the National Oceanic and Atmospheric Administration (NOAA) for nitrox diving. By the end of 1997, there were a total of 11 nitrox or mixed-gas certifying agencies in North America.

The growing popularity of enriched-air nitrox (EAN) and mixed-gas diving has encouraged DAN to produce an analysis of the limited injury data available on recreational mixed-gas diving.

In previous years there were not enough cases for meaningful analysis to collect and follow up on mixed-gas diving injuries. Between 1990 and 1994 DAN recorded only 31 cases. In 1995, 16 cases were sent to DAN and in 1996, 23 cases were sent in. The 1997 data is based on 30 scuba-certified divers using EAN or mixed gas who were injured and required treatment in a hyperbaric chamber. Because of the small numbers involved, DAN has chosen to put these dive accidents in a separate appendix for now.

In the past four years, there have been eight recreational deaths in which the divers were using mixed gas. In 1997, one death occurred; two deaths occurred in 1996; three occurred in 1995; and two in 1994 using mixed gas. These 1997 fatality cases are included in the fatality appendix of the report (Appendix A, Pages 80-108).

In 1997, there was an increase in the number of EAN and other mixed-gas divers contacting DAN for consultation. A total of 68 calls were made to the emergency line regarding mixed-gas diving. Forty-three of these divers reported symptoms consistent with decompression sickness, and 26 divers were treated with hyperbaric therapy.

There is no way of determining incidence results. This is because there is no way of knowing how many mixed-gas or EAN divers participate in diving each year or how many dives are made. While IANTD reports certifying approximately 17,780 U.S. nitrox divers from 1985 to 1996, it is nonetheless impossible to determine how many of these divers are still active in nitrox and mixed-gas diving.

The reported cases in this database are also not well distributed, with 16 of the 30 cases (62 percent) occurring in Florida. Two deaths each occurred in California and Washington. One case each was reported in Missouri, New Jersey, Maine, Pennsylvania, North Carolina, and Rhode Island. There were four deaths outside the U.S., in the Cayman Islands, Truk, Dominican Republic and Mexico.

Diver Characteristics

Divers trained in the use of mixed gases *do* differ from air divers in the amount of specialized training they receive and in the operational procedures they are required to follow when using oxygen-enriched diving mixtures. In addition, EAN and mixed-gas divers should be well informed about the potential for oxygen toxicity, a risk rarely encountered by a diver using compressed air but a more likely risk with mixed-gas diving.

In the 1997 injury population, there were four divers who used a nitrox mix with oxygen concentrations of greater than 40 percent oxygen; three were using an 80 percent oxygen mix as the gas mix used at their decompression stop.

Two divers in this population were diving with trimix (see Table E.1, below). As Table E.1 shows, not all of the divers using mixed gas were certified in its use. Three divers (10 percent) were uncertified in mixed-gas diving and procedures.

The gas mix used by the one diver who died in 1997 was nitrox. This diver was not certified in mixed-gas diving.

It is difficult to draw any conclusions about EAN and mixed-gas divers because of the small number of cases and the limited data. Characteristics of air divers can, however, be compared to those of mixed-gas divers.

The largest fraction of mixed-gas divers (43.3 percent) are in the 30-39 year age range. In contrast, air divers are more evenly distributed over the 25- to 49-year-old age range (Table E.2, Page 118). Mixed-gas certification often requires an advanced diver certification, and, likely, divers with more experience — this favors older divers. Also, there appears to be a trend towards participation of older divers (> 40) that may reflect a wider interest in this type of diving.

Males dominate the mixed-gas population, with 83 percent of all injury cases involving men, compared to 69 percent males in air-diving injuries. (Table E.3, Page 118).

Table E.1 *Mixed-Gas Certification by Gas Mix*

Gas Mix	Certified	Non-certified	Total
Nitrox (29%-37%)	19	2	21
Nitrox (> 40%)	4	0	4
Nitrox (80%-decompression stop mix)	2	1	3
Nitrox and Trimix	0	0	0
Trimix (O2-N2-He)	2	0	2
Heliox (O2-He)	0	0	0
TOTALS	**27**	**3**	**30**

Certification is based on having a certification as a mixed gas or technical diver.

Because most mixed-gas divers generally have an advanced certification, it is not surprising to find that a majority of these injury cases were certified at the advanced or instructor level (Table E.4, below). In contrast to air-diving injuries, almost all injuries in mixed-gas divers occurred in divers with more than 121 lifetime dives (80 percent). Fourteen (46.7 percent) of the divers had been diving for 10 years or more (Table E.5, Page 119, top).

Table E.2 ***Age Distribution of Nitrox or Mixed-Gas Injury Cases***

Age	1997	1996	1995
20-24	13.3	8.7	18.8
25-29	13.3	17.4	31.2
30-34	23.3	30.4	18.8
35-39	20.0	30.4	18.8
40-44	10.0	8.7	12.4
45-49	16.8	4.4	0.0
50-54	3.3	0.0	0.0
TOTALS	**100.0**	**100.0**	**100.0**

Table E.3 ***Sex of Nitrox or Mixed-Gas Injury Cases***

Sex	1997	1996	1995
Female	16.7	13.0	12.5
Male	83.3	87.0	87.5
TOTAL	**100.0**	**100.0**	**100.0**

Table E.4 ***Certification Level of Nitrox or Mixed-Gas Injury Cases***

Certification	Male	Female	Totals	1997	1996	1995
Instructor	10	2	12	40.0	39.2	43.7
Advanced	5	0	5	16.7	17.4	37.5
Divemaster	4	1	5	16.7	21.7	6.2
Basic/Open	3	1	4	13.3	17.4	6.3
Other	3	1	4	13.3	4.3	6.3
TOTALS	**25**	**5**	**30**	**100.0**	**100.0**	**100.0**

Table E.5 *Diver Experience Among Nitrox or Mixed-Gas Injured Divers*

Male/Female	Total Lifetime Dives							
Years Diving	0-20	21-40	41-60	61-80	81-100	101-120	121+	TOTAL
0-1	1*	0	0	1	1	0	0	3
2-3	0	0	1	0	0	0	2/1*	4
4-5	0	0	0	0	0	0	2/2*	4
6-7	0	0	0	0	0	0	3	3
8-9	0	0	0	0	0	0	1/1*	2
10-11	0	0	1	0	0	0	2	3
12-13	0	0	0	0	0	0	2	2
14-15	0	0	0	0	0	0	2	2
16-17	1	0	0	0	0	0	0	1
18-19	0	0	0	0	0	0	0	0
20-21	0	0	0	0	0	0	6	6
TOTALS	**2**	**0**	**2**	**1**	**1**	**0**	**24**	**30**

**Female divers*

Decompression Illness in Mixed-Gas Divers

"Decompression illness" is the general term for arterial gas embolism (AGE) and decompression sickness (DCS, which includes DCS I and DCS II).

The frequency of each diagnosis is shown in Table E.6 (below).

Approximately the same percentage of DCI cases were incidents of DCS II in mixed-gas divers (70 percent), compared to air divers (66.8 percent, Table 4.3, Page 46).

Two individuals (one male, one female) had symptoms of DCI but continued to dive. Their symptoms included pain, decreased skin sensations, fatigue and headaches.

Mixed-gas divers who used emergency oxygen first aid was 56.7 percent.

Four of the seven (57 percent) DCS I cases called for assistance within 12 hours, but one diver waited up to an additional 12 hours to report for recompression. One waited two days to call for assistance, and another diver waited three days.

Twelve of the 21 (57.1 percent) DCS II cases called for assistance within 12 hours; five more (23.8 percent) waited an additional 12 hours to call and report for treatment. Three individuals (14.3 percent) waited two days to call for assistance, and

Table E.6 *Conventional Disease Categories*

Final Diagnosis	Frequency	1997	1996	1995
DCS I	7	23.3	34.8	12.5
DCS II	21	70.0	65.2	87.5
AGE	2	6.7	0.0	0.0
TOTALS	**30**	**100.0**	**100.0**	**100.0**

one individual waited four days to call for assistance. Both AGE cases called for assistance within one hour of symptom onset.

Twelve out of 30 divers had residual symptoms after treatment. With this small a population, the binomial distribution (a standard statistical test) is used to estimate the incidence level. The 95 percent confidence limits are 16.6 - 46.5 percent which brackets the 33 percent incidence reported for air divers. This means that we cannot say that the chance of residual symptoms is any different between the two populations. Neurological residuals represented 42 percent of all residuals while pain represented 58 percent (19.2 percent had neurological residuals in air divers). The pain residuals lasted from two to seven days. The residual neurological symptoms lasted from one day to six weeks.

Table E.7 ***First Aid Used***

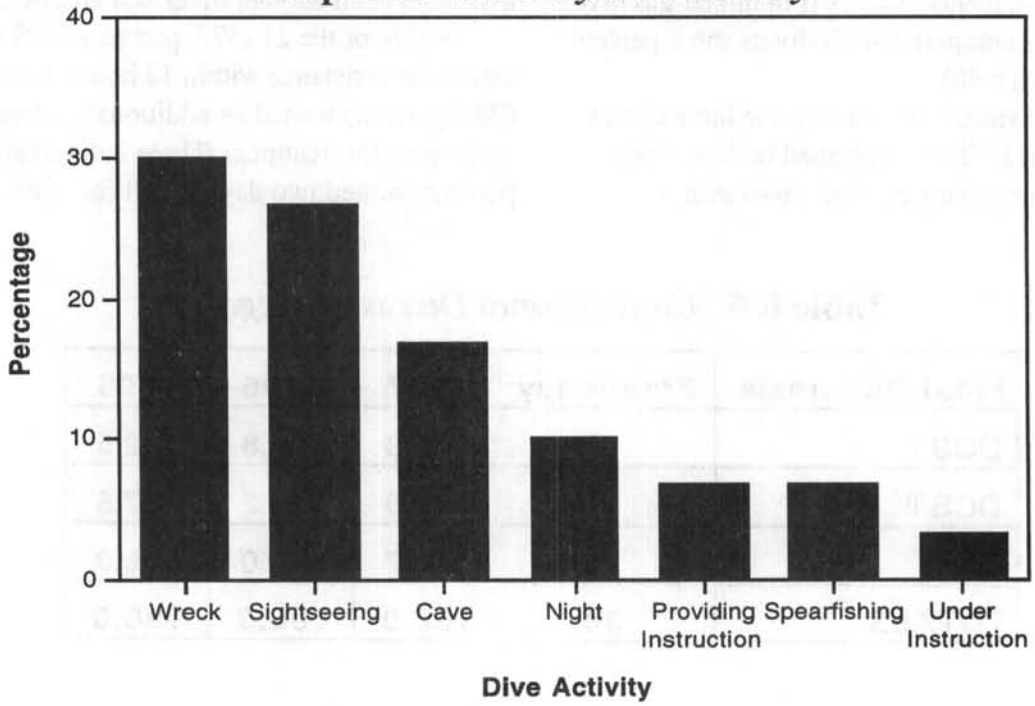
First Aid	1997 # of divers	1996 # of divers	1995 # of divers
Oxygen	17	10	12
Oral fluids	13	9	8
Aspirin	5	6	7
Position	2	1	3

Dive Profile Information

The activity of mixed-gas diving appears to be linked to more specialized dive activities, compared to that of recreational air divers (Graph E.1, below). Wreck and cave divers were among the first scuba divers to utilize mixed gases for recreational scuba.

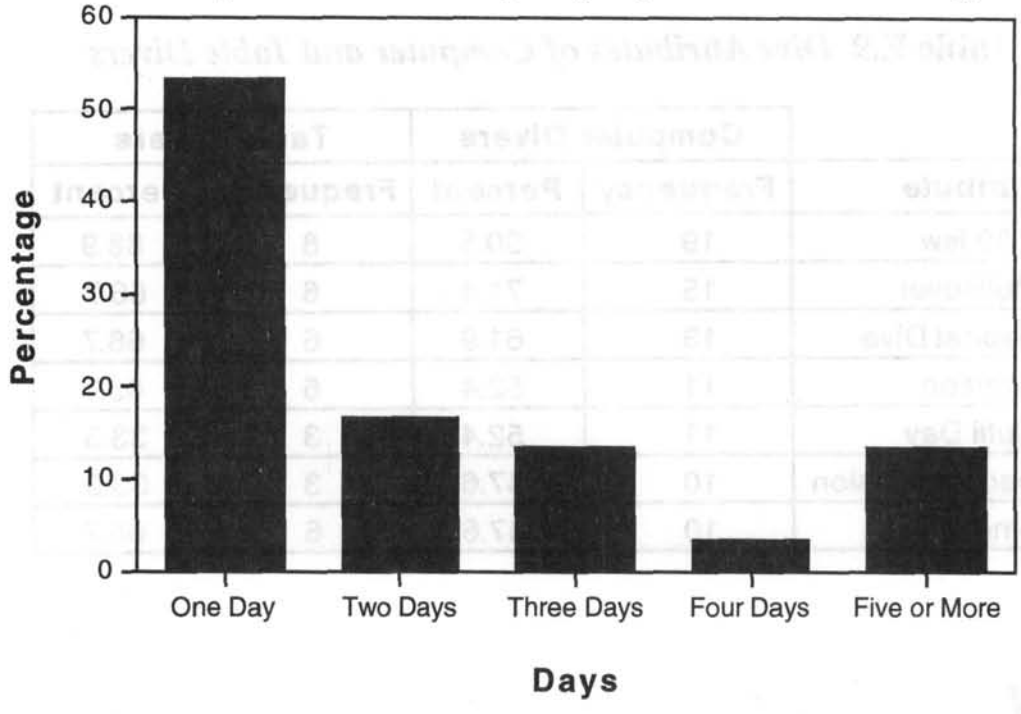
It is not surprising to find these activities are more popular in this limited population.

Graph E.1 ***Primary Dive Activity***



Sixteen of 30 divers (53.3 percent) were injured on the first day of diving (Graph E.2, below). The same trend is found in air divers, where 48.6 percent of injuries occur on the first day of diving. Mixed-gas divers tend to be more active divers, with 80 percent having been diving in the 30 days preceding their injury. This compares to 48.7 percent of recreational air divers.

Graph E.2 ***Number of Days of Continuous Diving***



The style of diving is different for mixed-gas divers and is reflected in the dive profile data (Table E.8, below). Comparison with data from divers injured on air dives (Table 3.1, Page 36) shows that mixed-gas divers tended to make deeper (≥ 80 fsw / 24 msw) dives, more decompression dives (43.3 versus 17.7 percent) and more single dives (40.0 percent vs. 31.7 percent). This probably means that mixed gas is used more for deep, complex dives involving decompression, presumably to take advantage of increased bottom time due to high oxygen partial pressure during decompression stops.

Table E.8 ***DCS Dive Attributes Among Mixed-Gas Injured Divers***

Attribute	Frequency	1997	1996	1995
≥ 80 fsw	27	90.0	91.3	81.3
No decompression	17	56.7	34.8	31.3
Exertion	17	56.7	30.4	50.0
Single Day	16	53.3	52.2	50.0
Current	16	53.3	30.4	43.8
Single Dive	12	40.0	60.9	62.5
Square	9	30.0	47.8	62.5
Rapid ascent	4	13.3	0.0	12.5

Seventy percent of mixed-gas divers (21 of 30 divers) were using a diver computer to help calculate their dive (Table E.9, below), which is greater than the 59.5 percent of air divers that were using a dive computer.

Among the 30 mixed-gas divers, no one mentioned having an equipment problem. This probably reflects the higher level of training, preparedness and familiarity with equipment in this population.

Table E.9 ***Dive Attributes of Computer and Table Divers***

	Computer Divers		Table Divers	
Attribute	**Frequency**	**Percent**	**Frequency**	**Percent**
≥ 80 fsw	19	90.5	8	88.9
Multilevel	15	71.4	6	66.7
Repeat Dive	13	61.9	6	66.7
Exertion	11	52.4	6	66.7
Multi Day	11	52.4	3	33.3
Decompression	10	47.6	3	33.3
Single Day	10	47.6	6	66.7

Summary

Like computer-assisted diving, mixed-gas diving appears to be a permanent part of the recreational diving community. It will be several years until sufficient data has been collected by DAN to do a more thorough comparison of mixed-gas and air diving injuries.

Although mixed-gas diving is becoming more common, it appears to be practical for only a small group of divers because it has a high-profile "technical" appearance, which may not be consistent with the general public's view of recreational scuba diving.

The injuries reported among mixed-gas divers are not unlike those injuries reported in air divers. The fraction of injuries reported as DCS II and the number of residual symptoms after treatment are similar in the two groups. The main distinction, however, is that a higher fraction of residuals in mixed-gas divers were neurological, compared to air divers.

The higher fraction of neurological residuals in these divers is cause for concern. The delay in calling for assistance appears similar for mixed gas and air divers so this probably doesn't account for the observation. More likely is that mixed-gas divers make a larger fraction of long, deep decompression dives: this type of dive tends to produce more severe neurological symptoms, and when they do occur, these symptoms tend to be more difficult to treat.

There are risks with mixed-gas diving not present at the same depths in air diving: one such hazard is oxygen toxicity, which is potentially fatal at depth. Oxygen toxicity seizures have been reported in both near-miss and fatal diving incidents.

The decision to use mixed gas in a reasonably safe manner must include proper training and certification through one of the many training associations. It must also include the acknowledgment that mixed-gas diving has additional risks, and greater caution must be extended to improve these risks.

Appendix F
Diving Definitions

Arterial Gas Embolism — Also referred to as AGE, a condition in which gas bubbles enter the arterial system and cause damage by blocking blood flow to vital organs, most commonly the brain. This is generally caused by air passing through the walls of the alveoli into the bloodstream.

Buoyancy Control — The ability to maintain neutral buoyancy. Common causes of buoyancy problems include a current pushing a diver either up or down, being either over- or under-weighted, overinflation of the buoyancy compensator, or lack of the actual skill.

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

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

Decompression Diving — Diving exposure requiring staged in-water stops before ascent to the surface.

Decompression Illness — Also referred to as DCI, decompression illness is a term to describe dysbaric injuries related to scuba diving. This diagnosis stems from the uncertainties in many cases about the mechanistic causation of neurological symptoms. Moreover, it is sometimes impossible to differentiate clinically between neurological DCS and AGE. An alternative approach has been suggested in which the clinical manifestation of a patient's decompression syndrome is described without attempting to determine the pathophysiology. The term "decompression illness" (DCI) is suggested to encompass all manifestations of diseases following a reduction in ambient pressure, such as ascending from a dive.

Decompression Sickness — Also referred to as DCS, a syndrome caused by bubbles of inert gas forming in the tissues during or after ascent from a dive. DCS is manifested in two major forms, DCS I and DCS II. In contrast to AGE, where bubbles may be transported long distances from where they form (lung) to where they cause damage (brain), in DCS bubbles usually cause damage in close proximity to where they are formed.

> **DCS I** — decompression sickness involving only muscle and joint pain, fatigue and/or skin symptoms (itching, rash).
>
> **DCS II** — decompression sickness that includes any symptom involving the central nervous system, respiratory system or circulatory system.

EAN (Enriched-Air Nitrox) — A nitrogen/oxygen mixture containing more than 21 percent oxygen, usually made by mixing air and oxygen.

Exertion — Exercise above that required for a relaxed swim in calm water. The main causes of exertion during a dive are current or extra equipment (such as for photography or specialty diving).

Fatigue — Complaints of being tired, experiencing a lack of sleep or a generalized tiredness.

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

< Two Years' Experience — The diver had been diving for less than 24 months on the day of interest.

Heliox — Helium and oxygen mixes.

Mixed Gas — Any breathing medium that was mixed using oxygen and other gases, most commonly, helium, nitrogen, or air. Mixed gas could have only a single inert gas (e.g., heliox, nitrox) or multiple inert gases (e.g., trimix — nitrogen, helium and oxygen mixes: see next page).

Multiday — When more than one day of diving was performed in this particular dive series with a surface interval of < 24 hours between consecutive dives. Multiday and single-day are mutually exclusive.

Multilevel Dive — A dive in which the diver remains at several depths for a period of time before beginning final ascent to the surface: this contrasts with square dive, which involves a singe depth (see next page). Many different levels can be visited in one dive before finally ascending — for example, a diver descends to 60 feet / 18 meters and stays for 10 minutes then descends to 80 feet / 24 meters and stays for five minutes, ascends to 50 feet / 15 meters for 10 minutes and then to 20 feet / 6 meters for five minutes before surfacing.

Nitrox — A nitrogen-oxygen mixed gas that contains an oxygen percentage other than 21 percent. "Oxygen-enriched air" or "enriched-air nitrox" refer to nitrox mixtures with oxygen levels greater than 21 percent. The most common nitrox mixtures are NOAA Nitrox I and NOAA Nitrox II, 32 percent oxygen and 36 percent oxygen, respectively.

No-Decompression — A dive not requiring a staged stop during ascent to the surface. This type of dive can be made with either tables or computers.

Rapid Ascent — Ascending from a dive faster than the currently recognized recommended ascent rate of 60 feet / 18 meters per minute. Rapid ascents are often uncontrolled and can be caused by over-inflation, poor buoyancy control, being under-weighted or by panic.

Repeat Dive / Repetitive Dive — More than one dive was made on the day of interest, with some period of time spent at the surface between dives (surface interval). "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, but rather a single day of diving (for example: four dives could be made in a single day: or a single day of diving could include one dive only).

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

Square Dive — A dive in which a diver descends to a single depth and remains until beginning the final ascent to the surface. This contrasts with multilevel dive, (see Page 123): for example, a diver descends to 60 feet / 18 meters and stays at 60 feet for 30 minutes before ascending. Square dives and multilevel dives are mutually exclusive.

Technical Dive — In this report, a technical dive is defined as one in which one of the following conditions existed:

- Diving deeper than 130 feet / 40 meters;
- Using a breathing mixture other than compressed air;
- Decompression or overhead diving (in shipwrecks, caves or under ice);
- Special training and equipment were used, such as rebreathers.

Trimix —Nitrogen, helium and oxygen mixes.

Within Limits — represents divers who were diving within their computer or table limits.

Appendix G

Abstracts – 1997-98

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Dear GdeL, Vann RD, Pieper CF, Bute BP, Uguccioni DM, Thalmann ED. DCI Symptoms Do Not Appear to Form Syndromes. Undersea and Hyperbaric Medicine 24 (Suppl); A144: 33, 1997.

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Appendix H

Total Reported Cases by Year and Region: 1986 - 1994

1994	Other*	SW	NW	MW	GU	PA	NE	SE+	TOTALS
DCS-I	3	39	13	13	26	1	39	93	227
DCS-II	14	59	50	24	68	8	85	336	643
AGE	2	18	5	2	16	15	3	30	91
No case breakdown	14	40	0	11	1	77	6	53	202
TOTALS	**33**	**156**	**68**	**50**	**111**	**101**	**133**	**512**	**1,163**

1993	Other*	SW	NW	MW	GU	PA	NE	SE+	TOTALS
DCS-I	3	33	12	9	22	10	37	92	218
DCS-II	18	90	42	33	75	52	40	292	642
AGE	1	13	10	2	1	13	4	44	88
No case breakdown	3	0	0	0	0	0	0	7	10
TOTALS	**25**	**136**	**64**	**44**	**98**	**75**	**81**	**435**	**958**

1992	SW	NW	MW	GU	PA	NE	SE+	TOTALS
DCS-I	25	17	20	24	21	43	82	232
DCS-II	59	47	27	59	63	24	276	555
AGE	11	6	4	10	0	6	39	76
No case breakdown	0	0	0	0	0	0	13	13
TOTALS	**95**	**70**	**51**	**93**	**84**	**73**	**410**	**876**

1991	SW	NW	MW	GU	PA++	NE	SE+	TOTALS
DCS-I	34	12	6	32	0	40	109	233
DCS-II	83	21	21	22	1	49	240	437
AGE	26	2	8	9	0	6	36	87
No Dx reported	0	0	0	0	57	0	0	57
No Treatment**	1	0	0	0	1	0	4	6
TOTALS	**144**	**35**	**35**	**63**	**59**	**95**	**389**	**820**

1990	SW	NW	MW	GU	PA++	NE	SE+	TOTALS
DCS-I	31	8	17	31	0	28	111	226
DCS-II	60	8	10	37	0	34	193	342
AGE	13	1	2	7	0	15	58	96
No Dx reported	0	0	0	0	31	0	7	31
TOTALS	**104**	**17**	**29**	**75**	**31**	**77**	**362**	**695**

Total Reported Cases by Year and Region: 1986 - 1994

1989	SW	NW	MW	GU	PA++	NE	SE+	TOTALS
DCS-I	48	12	18	11	0	14	78	181
DCS-II	64	15	17	29	0	47	156	328
AGE	35	3	3	1	0	4	65	111
No Dx reported	0	0	0	0	58	0	0	58
TOTALS	**147**	**30**	**38**	**41**	**58**	**65**	**299**	**678**

1988	SW	NW	MW	GU	PA++	NE	SE+	TOTALS
DCS-I	14	9	11	13	0	22	68	137
DCS-II	43	27	10	25	0	32	151	288
AGE	25	6	2	1	0	10	38	82
DCS-AGE combined	1	0	0	4	0	0	5	10
No Dx reported	0	0	0	0	36	0	0	36
No treatment**	0	3	0	1	1	2	5	12
TOTALS	**83**	**45**	**23**	**44**	**37**	**66**	**267**	**565***

1987	SW	NW	MW	GU	PA++	NE	SE+	TOTALS
DCS-I	15	4	2	15	0	30	61	127
DCS-II	58‡	25	12	20	0	26	199	340
AGE	20	4	2	6	0	6	59	97
No Dx reported	0	0	0	0	38	0	0	38
No treatment**	2	0	0	0	0	3	17	22
TOTALS	**95**	**33**	**16**	**41**	**38**	**65**	**336**	**624**

1986	SW	NW	MW	GU	PA++	NE	SE+	TOTALS
DCS-I	0	6	2	1	0	0	68	77
DCS-II	69‡	11	13	8	7	33	133	274
AGE	28	2	0	0	0	10	41	81
No Dx reported	0	0	0	0	25	0	97	122
No treatment**	3	0	0	0	0	1	4	8
TOTALS	**100**	**19**	**15**	**9**	**32**	**44**	**343**	**562**

* *Includes all foreign countries and U.S. military personnel (these cases involved active-duty military personnel who were diving recreationally and treated in military chambers).*

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

\+ *SE includes Caribbean basin.*

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

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

Notes: