Recreational Diving Fatalities Workshop
Summary*

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The risks of dying during recreational diving are small. The purpose of this workshop was to consider how the risks might be reduced further. Topics included investigation, surveillance, training and operational safety, and cardiovascular disease. Investigations involve on-scene inquiry, forensic examination of the deceased and life-support-equipment testing. These are essential to determine causes but are often inadequate. Independent annual fatality rates were presented and reviewed for diving, jogging and motor vehicle accidents and for divers in training. Common factors associated with diving fatalities included running out of gas, entrapment or entanglement, buoyancy control, equipment misuse, rough water and emergency ascent. Asphyxia by drowning, air embolism and cardiac events were the principal injuries or causes of death. About one-quarter of the deaths were associated with cardiac events, mostly in older divers. Revised procedures were recommended for identifying occult cardiovascular disease in candidate divers who warrant further investigation, but older, previously certified divers may be at greatest risk.

Introduction

The risk of dying during recreational diving is small, but no activity is completely risk-free, and deaths occasionally occur. Improved countermeasures might be devised if contributing factors were identified. Studies of the causes and annual rates of recreational diving fatalities suggested this might be feasible (Denoble, Caruso et al. 2008; Denoble, Pollock et al. 2008), and this workshop was convened to explore the possibilities. Topics addressed included investigation, surveillance and data analysis, training and operations, and cardiovascular disease. The workshop findings are summarized below. The four cardiovascular papers published in these proceedings (Bove 2011; Thompson 2011; Douglas 2011; Mitchell, Bove 2011) were reprinted with permission from Undersea and Hyperbaric Medicine.* The proceedings (Vann, Lang 2011) and presentation videos from the workshop are available on the DAN website (www.DAN.org) at no cost.

Workshop participants were encouraged to base their comments on evidence rather than opinion, and this approach was generally observed. During planning, one individual offered to present his opinion but declined to attend when asked to provide supporting data. The absence of evidence makes judging the validity of opposing opinions difficult, can lead to personal animosity and is counterproductive to useful public discussion.

Participants in the training panel were concerned in advance that the discussions might increase their liability, and several training agencies declined to attend.

*This summary and the four cardiovascular papers listed below are reprinted with permission from Undersea and Hyperbaric Medicine.


To allay these worries insofar as possible, the training panel was not recorded as the other sessions were, although the topics discussed are presented in these proceedings.

Unsupported opinions were most common in the training and operations discussion and occasionally resulted in sharp exchanges. Some of the topics raised were useful, but the acrimony was not. Accordingly, a summary of the key points from the training and operations discussion is presented rather than a verbatim transcript as for the other sessions.

**Investigation**

In the United States, the Coast Guard and/or state law enforcement agencies have authority over diving fatalities that occur in most U.S. waters. Law enforcement organizations are charged with determining criminal culpability but not investigating causes. A local coroner or medical examiner may be responsible for establishing the cause of death (COD) but is frequently unfamiliar with the special requirements of diving autopsies that differentiate among causes such as drowning, air embolism and decompression sickness (Caruso 2011). Often, agencies are not well coordinated nor do they have the resources or capabilities for comprehensive investigation.

The ideal investigation would begin immediately with a trained individual conducting an on-scene inquiry that included equipment inspection, a dive site survey and interviews with witnesses, dive professionals and public safety personnel (Barsky 2011). Life-support equipment should be impounded and preserved at once. A factual written report should summarize the findings with additional documentation by still photography. Videos of the site and/or equipment may supplement the report as needed. Forensic examination of the deceased would identify the COD and contributing medical factors in the context of operational reports (Caruso 2011).

Life-support equipment for compressed-gas diving is generally robust and reliable, but poor maintenance, improper use or design flaws can compromise its operation and contribute to events leading to death (Bozanic, Carver 2011). Equipment should be treated as evidence rather than personal property, and standard chain-of-custody procedures followed to minimize loss or damage. Forensic testing can determine if equipment was a contributing factor, but testing is expensive, few qualified personnel and facilities are available, and testing may be futile if equipment deteriorates due to long delays.

Investigations are often at the behest of an insurance company, which hires a private investigator with the objective of determining liability (Concannon 2011; Jaeck 2011). Inadequate investigation is a source of distress to the deceased’s family and an impediment to understanding the causes of death. The probability of litigation increases when the events and causes are not discovered. Both U.S. and European courts are requiring strict adherence to evidence preservation such as data contained in a dive computer.

Thorough investigations are unusual because there are few trained investigators, but improvements should be achievable. These include: (a) readily available investigation protocols and checklists that are published in these proceedings (see Pages 223-282) and can be downloaded from the DAN website (www.DAN.org); (b) chain of custody procedures for equipment; (c) training of first responders in investigation procedures; (d) collaboration among investigative organizations; (e) standardized equipment test protocols; and (f) national and international case reporting.
Diving Fatality Surveillance

Diving is not unique in its capacity to cause injury, and surveillance is an essential epidemiological tool to identify associated factors (Kucera, Marshall 2011). These factors are the basis for countermeasures to improve safety with regular follow-ups to assess countermeasure effectiveness. Diving fatality surveillance programs were described for the United States, Canada and Europe (Denoble et al. 2011); Australia and the Pacific region (Lippmann 2011) and the United Kingdom (UK) (Cumming et al. 2011). Annual per capita fatality rates among DAN America (16.4 deaths per 100,000 persons per year) and the British Sub-Aqua Club (BSAC) members (14.4 deaths per 100,000 persons per year) were similar and did not change during 2000-2006, the period examined (Denoble et al. 2011). Annual per capita fatality rates during jogging (13 deaths per 100,000 persons per year) and motor vehicle accidents (16 deaths per 100,000 persons per year) were comparable and within the range where reduction is desirable by UK Health and Safety Executive (HSE) criteria (Denoble et al. 2011).

Richardson reported data for 17 million student-diver certifications during 63 million student dives over a 20-year period (1989-2008) during which no trend in annual fatality rate was apparent (Richardson 2011). The mean per capita death rate during this period was 1.7 deaths per 100,000 student divers per year. This was lower than for insured DAN members during 2000-2006 at 16.4 deaths per 100,000 DAN members per year (Denoble et al. 2011), a statistically significant difference (p<0.0001 by chi-square test). Per capita fatality rates are poor measures of exposure risk, however, and may not be informative of true risk. Thus, the tenfold lower per capita rate between student divers and DAN members may not represent a tenfold lower exposure risk.

Fatality rate per dive is a better measure of exposure risk, and Richardson reported a mean annual fatality rate of 0.48 deaths per 100,000 student dives per year (Richardson 2011), while Cumming et al. (2011) reported 0.54 deaths per 100,000 BSAC dives per year and 1.03 deaths per 100,000 non-BSAC dives per year during 2007. Naïve comparison of these per-dive rates suggests the difference in risk between diving during organized courses and during non-course dives is less than tenfold, but this conclusion could not be tested statistically since the BSAC rates were based on survey estimates rather than on logged dives as reported by Richardson.

The above review indicates that the difference in risk of death between organized training-course dives and non-course dives was difficult to distinguish in data presented at the workshop. This argues for independent information, and diving training agencies and diver membership organizations are encouraged to publish data similar to that described by Richardson (Richardson 2011). Moreover, the total size of the diving population is important for determining overall fatality rates, and the population estimates from the 1990s of several million U.S. divers need to be updated (Hornsby 2011).

Fundamental problems associated with diving fatalities have not changed significantly in recent history (Denoble et al. 2011; Lippmann 2011; Cumming et al. 2011; Richardson 2011). The most frequently cited root cause among the independent population samples was insufficient gas or running out of gas. Other common factors included entrapment or entanglement, buoyancy control, equipment misuse or problems and rough water. Emergency ascent was also common. The principal injuries or causes of death included drowning or asphyxia due to inhalation of water, air embolism and cardiac events. Older divers were at greater risk of cardiac events, with men at higher risk than women, although the risks were equal at age 65 (Denoble, Pollock et al. 2008).
Operational Diving Safety
A discussion of diving safety based on operational experience cited many of the risk factors mentioned above (Vann, Lang 2011). Divers are taught to avoid most of these during training, but many who died seemed not to have acted in accordance with instruction. It was unclear why this was so. Suggested countermeasures included skill refreshers with check-out dives, buoyancy control rehearsals and gas management and alternate air source practice. Fatal entanglement might be prevented by carrying a cutting device. Obstructed overhead environments should be avoided (without proper training) to prevent entrapment.

Unsubstantiated opinions concerning contributing factors were common, and although many seemed plausible, validation by empirical evidence is needed. Suggested contributing factors included inexperience, infrequent diving, inadequate supervision, insufficient predive briefings, buddy separation and dive conditions beyond the diver’s training, experience or physical capacity.

Given that divers who died often seemed to forget their training, the editors created a diving safety “quiz” (see Appendix C) as a reminder to recreational divers of key safety factors. It is offered for general community use without permission as a handout, dive magazine filler, website post, poster, etc.

Cardiovascular Risk Assessment
Given that cardiac events are associated with about a quarter of recreational diving fatalities that were investigated (Denoble, Caruso et al. 2008), current screening methods appear inadequate for identifying divers at risk of sudden cardiovascular death. The most common causes of sudden death in the general population are arrhythmia and acute myocardial infarction (Thompson 2011), usually due to occult cardiovascular disease with little prior indication of abnormality (Douglas 2011). Divers face additional stresses from immersion and cold, which cause a central shift of blood and can lead to acute volume overload and decompensated heart failure (Bove 2011). Ischemia and arrhythmia may be aggravated during exercise due to increased blood pressure and sympathetic activation. Dive site survival might improve if divers and diving personnel were trained to recognize the signs and symptoms of cardiac events and to offer basic emergency assistance.

Prevention is preferred to emergency response, however, and two groups are potentially at risk. The first is candidate divers who seek to enroll in initial diving training. For this group, medical screening is generally based on a questionnaire such as the Recreational Scuba Training Council (RSTC) form on which an answer indicating a possibly disqualifying medical condition requires physical examination (RSTC 2010). The workshop reviewed the RSTC form and suggested revisions to its questions based on the AHA preparticipation questionnaire for competitive athletes (Maron et al. 2007). Risk factors discovered during subsequent examination were categorized as contraindications for diving or as grounds for further investigation. Further investigation included a stress test to demonstrate that a candidate diver can sustain exercise at an intensity of 6 MET (multiples of assumed resting metabolic rate) (Mitchell, Bove 2011).

The second at-risk group is established older divers who have developed occult cardiovascular disease in the years since initial training and appear to be at greatest risk (Denoble, Caruso et al. 2008; Denoble, Pollock et al. 2008). Appendix G is a “Divers Self-Assessment Checklist for Cardiovascular Health” that might be used before charter boat dive trips, prior to continuing diving education courses, etc.
References


