

The Forensic Investigation of Recreational Diving Fatalities

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Diving using scuba, or any type of diving using compressed breathing gas, remains a popular pastime in the United States and worldwide. Present estimates place the number of active recreational divers in the United States at between 2.7 to 3.5 million (Hornsby, Page 165). The number of fatalities involving U.S. citizens performing recreational dives averages 90-100 each year. From a dive safety perspective, these deaths should be thoroughly investigated to determine a trigger, or root cause, for the mishap. Proper data collection and analysis allows identification of the most common triggers and contributing factors associated with fatal diving mishaps.

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Introduction

Monitoring the epidemiology of diving fatalities allows diver training organizations and dive safety organizations to make recommendations for improved instruction and safer diving habits. It is hoped that such changes in training and dive protocol will result in fewer fatal diving accidents and fewer diving-related injuries overall.

From a forensic pathology point of view, these fatalities challenge the investigators and pathologists who must investigate and certify these deaths. Except in a select few jurisdictions, such as Miami and San Diego, diving fatalities are rare enough that most forensic pathologists have little experience in this area. There are a few specialized techniques that can be utilized during the performance of the autopsy to help maximize the amount of information obtained. At least a basic understanding of diving physics and diving physiology is required to properly interpret the findings of a postmortem examination. The forensic pathologist also needs to understand the limitations of autopsy findings in diving-related deaths and realize that there are common postmortem artifacts that can be misinterpreted, resulting in erroneous conclusions.

Another item that cannot be overlooked is the fact that recreational diving fatalities are often litigated in civil court and occasionally in a criminal court. It is in the public's best interest that any lawsuits or criminal charges resulting from a diving-related death be based on sound conclusions from a properly investigated mishap.

The most important step in investigating a fatal diving mishap is obtaining a complete history. Certainly a detailed dive profile is essential, but also the decedent's past medical history and the decedent's health status and behavior prior to the dive are extremely important components of the investigation. A thorough post-mortem medicolegal autopsy along with toxicological testing should be the standard of care. Dive equipment used by the deceased diver needs to be impounded immediately and examined by an expert who has no stake in the results. If there is any breathing gas remaining, it should be analyzed in accordance with industry standards.

Diving medical professionals are an invaluable resource for the proper investigation of diving-related fatalities. A savvy medical examiner should seek out clinical colleagues with expertise in dive medicine when faced with investigating diving-related fatalities. As a corollary, medical professionals with expertise in dive medicine should offer to assist in the investigation of diving-related deaths, and being present during the autopsy would be ideal.

The proper investigation of diving-related deaths and public dissemination of the most common health issues, dive practices and behaviors that result in or contribute to a fatal dive mishap are fundamental to improving dive safety. Collaboration is required among the authorities responsible for investigating these deaths, the clinical dive medicine community and the dive training and dive safety organizations.

Forensic Investigators and Forensic Pathologists

Forensic investigators are individuals who possess special training and experience in the field of death investigation. While there are a variety of training pathways and backgrounds that lead to a career in death investigation, many forensic investigators have prior law enforcement or military experience. A significant number have college degrees, and some even have advanced degrees. Most will seek national certification in death investigation.

Forensic pathologists are physicians who after completing medical school go on to complete an additional three to five years of training in pathology, the medical specialty that focuses on diseases and disease processes. After training in general pathology, an additional year of training in forensic pathology is required. Board certification by formal examination is typical.

Forensic pathologists and forensic investigators are extremely skilled at evaluating deaths that are sudden, non-natural, unexpected or suspicious in any way. Much of the casework centers on violent deaths, such as assaults and accidents, and unattended deaths that appear to be natural. Diving-related deaths are rare compared to other types of deaths that come to the attention of the medical examiner's office. Another individual who may be involved in the investigation of a diving death is a coroner. Coroners do not have to be medically trained, though some are. States have different systems for the certification of deaths. If a state has a coroner system, the coroner typically certifies the death and signs the death certificate, but he or she would have a forensic pathologist perform the postmortem examination on the remains. Most, but not all, forensic autopsies are performed by forensic pathologists. Occasionally, a general pathologist who has not completed formal forensic training will be tasked with performing a postmortem examination on someone whose death appears to be non-natural. Fortunately, that is the exception rather than the rule.

Select offices have significant experience with diving-related deaths. Dade County (Miami), San Diego County, Honolulu and Monroe County (Key West) are examples of jurisdictions that typically investigate several diving-related deaths each year. Other jurisdictions may see as few as one diving-related death every few years, and the experience with certifying cause and manner of death for these cases would be minimal.

Death Certification

Death certificates are legal documents that list very detailed demographic information about the deceased, important chronological data such as the date and time of the death, and, most important, the cause and manner of death. Cause of death

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is defined as the injury or disease that produces a physiological derangement in the body that results in the death of the individual. Examples include a gunshot wound, lung cancer, blunt-force injuries and drowning. The list is extensive, and the possibilities are innumerable. Manner of death is the category of circumstances under which death occurred and can only be one of five possibilities: natural, accident, homicide, suicide and undetermined. Manner of death essentially explains how the cause of death came about. Typically, the cause of death is determined by the autopsy, and the manner of death is determined by the investigation.

The Medicolegal Autopsy

A complete medicolegal autopsy consists of several steps, all of which are important to the ultimate goal of determining an appropriate and correct cause and manner of death. A proper investigation of the events leading up to the death is essential. If the autopsy is the final physical examination on a deceased individual, the investigation is the history component. A pathologist should not perform an autopsy without at least reviewing a preliminary investigative report. Prior to beginning the autopsy, some cases warrant radiographic studies. These range from postmortem CT imaging to simple head and neck radiographs.

While standard hospital autopsies focus on a detailed description of the internal organs and the natural disease processes that affect them, forensic autopsies stress a thorough external examination looking for injuries, injury patterns, trace evidence and clues to how the body and the environment may have interacted. It is not unusual for the external examination portion of a medicolegal autopsy to take every bit as long as, or longer than, the internal examination. Extensive photodocumentation plays a significant role in the external examination, and digital photography has made this part of the postmortem exam infinitely easier.

Once a thorough external examination is completed, the internal examination portion of the autopsy begins. Organs are examined in situ, removed, weighed and thoroughly examined. An important component of the internal examination is obtaining adequate toxicology samples, including blood, urine, vitreous fluid, bile, gastric contents and portions of various solid organs such as liver, spleen, kidney and brain. Once the organs have been removed and examined, the autopsy concludes with an inspection of the skeleton, particularly the ribs, spine and skull.

After the autopsy examination is completed the pathologist releases the remains of the deceased individual to the next of kin. Depending on what the pathologist finds during the autopsy examination, some ancillary studies may be indicated. Microscopic slides of select organs, particularly the lungs, heart, liver and brain, may be prepared. In some cases the pathologist may choose to retain complete organs, such as the brain or heart. An official consultation on these organs may be requested. There are subspecialists, neuropathologists and cardiovascular pathologists, who concentrate on diseases of one specific organ system. Toxicological testing was already mentioned, and for all medicolegal autopsies this is an essential part of the examination. It would be important to know if the diver had been under the influence of any sedating medications or illicit drugs, for example. In diving-related deaths the blood should be tested for the presence of carbon monoxide as that would point the investigation toward tainted breathing gas and also suggest the possibility that other divers may be affected if other cylinders containing impure gas are circulating.

Of course, no death investigation that concerns a diver is truly complete without an evaluation of the equipment. Guidelines concerning the evaluation of dive

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equipment are covered in this volume (Barsky 2011; Bozanic, Carver 2011), but the forensic pathologist needs to know if the equipment played a significant contributing role in the death of the diver. Equipment problems seldom directly cause the diver's death, but the diver's response to an equipment malfunction, especially if the response is panic and perhaps a rapid ascent to the surface, may be the catastrophic event in the sequence that results in a diving-related fatality.

Once all of the investigative reports, the equipment evaluation and all of the components of the postmortem examination, including toxicological testing, are available to the pathologist, a final autopsy report can be generated. Such a report should provide a detailed description of the autopsy findings and include a synopsis of the circumstances surrounding the death as well as the results of all ancillary studies. A good autopsy report also includes a summary and interpretation section that cites the professional opinion of the pathologist who performed the autopsy.

Specialized Autopsy Techniques for Diving-Related Deaths

A recommended protocol for performing a postmortem examination on an individual who died while involved in a dive is included in Appendix F of these proceedings. While most forensic pathologists will have a similar approach to performing a medicolegal autopsy to what was outlined above, there are a few techniques that can be employed to maximize the yield of a postmortem examination in a diving-related death. There are also areas that warrant special attention. The investigative report must include important pieces of information such as the diver's certification status and level of training and experience. Knowing the dive profile and the circumstances surrounding the death are essential. With the near universal use of dive computers, they become an invaluable resource for the investigation. Not only can the final dive or dive series be reviewed, but many computers have large memories that store hundreds of dives. The diver's experience and dive habits can be reviewed. If the death occurred in the ocean, the external examination should include documentation of any evidence of a bite, sting or other possible means of envenomation.

The diagnosis of fatal air embolism rests as much or more upon the dive profile than on the autopsy findings. However, corroborating evidence of pulmonary barotrauma found during the autopsy can substantiate the diagnosis of air embolism. Subcutaneous emphysema can be appreciated during the external examination. Mediastinal emphysema and pneumothorax can sometimes be appreciated with postmortem radiographic imaging. There are recommended alterations in the internal examination that may also yield useful information. The pathologist should always check for a pneumothorax and intracardiac/intravascular gas during the postmortem examination of anyone who died while breathing compressed gas.

Two approaches are commonly used to check for a pneumothorax. During the initial incision to open up the chest, the pathologist can make a pocket of soft tissue over the chest wall, fill that pocket with water and check for escaping gas as the chest wall is opened. A technique that I find more useful and far less messy is to carefully make the initial entry into each pleural cavity by teasing away the intercostal muscles with the scalpel. As the pleural cavity is breached, careful observation of the parietal and visceral pleura will be enlightening. If a pneumothorax has occurred, the lung volume would have already been decreased, and as the parietal pleura is cut, the lung will be observed down in the pleural cavity. In the normal situation, the visceral and parietal pleura are up against each other and the lung does not fall away from the chest wall until the pathologist's scalpel gets through the parietal pleura.

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Careful observation for gas in the coronary arteries and in the arteries at the base of the brain should be made. Gas in the superficial veins of the cerebral cortex or the venous sinuses is not nearly that helpful. Tying off the arteries in the neck prior to opening the head and removing the brain decreases the chances of air being introduced into the cerebral arteries as an artifact.

The observation of intravascular and/or intracardiac gas during the autopsy of someone who died after breathing compressed gas can be very confusing and certainly does not indicate that an air embolism has occurred. Postmortem off-gassing does occur when the body sits at surface atmospheric pressure. Gas can be present in blood vessels and in the chambers of the heart after any type of dive, but the chances increase with long dives of sufficient depth resulting in large quantities of dissolved gas, typically nitrogen, in the body. Interpretation of intravascular gas at autopsy must be carried out with great care. The postmortem interval affects the amount of intravascular gas present at autopsy as gas is produced during the decomposition process. It is most important to take into account the dive profile. If the dive profile did not include an ascent, there is no possibility of an air embolism. I have seen experienced forensic pathologists erroneously decide that an air embolism contributed to a diver's death, even though the body was recovered from a deep cave system or a wreck without any possibility of an ascent during the dive.

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Diving Professionals and the Medical Examiner's Office

Diving-related deaths, because of the circumstances under which they occur, nearly always fall in the domain of the medical examiner or coroner. How a case is handled once the medical examiner's office gets involved is highly variable and is influenced in no small part by the experience level that office has with these types of cases. Offices that handle diving-related deaths with some frequency often have a protocol in place for the evaluation of the equipment and the handling of the remains. It is not unusual for an office that sees very few diving-related deaths to treat them as presumptive drowning, and in some cases an autopsy will not even be performed. This is very unfortunate as an autopsy is an essential piece in the thorough investigation of a diving-related death and in my opinion needs to be performed in all suspected drowning deaths, let alone diving-related deaths.

The diving professional, whether dive instructor, divemaster, dive shop owner or dive medicine expert, can play a very significant role in the medicolegal investigation of a diving-related death. It is the rare forensic investigator who possesses a background in diving physiology that is sufficient enough so that the right questions are asked. As is the case for all death investigations, the first few hours after the death occurs is the best time for interviews and data collection. Likewise, few forensic pathologists have a thorough enough grasp of diving physiology to completely understand the possible contribution of the deceased diver's training and experience, the dive profile or equipment issues to a diving-related death.

For all of the reasons cited, it is extremely advantageous for the medical examiner or coroner to accept the assistance and input of experienced divers. The goal of correctly certifying the cause and manner of death can best be achieved by a collaborative effort. The diving community benefits by having diving-related deaths thoroughly and properly evaluated so that risky behaviors, poor decision making or, in rare cases, equipment problems may be identified and publicized. Generating “lessons learned” with the hopes of decreasing the number of future diving-related deaths will make diving a safer endeavor for all of us.

Additional Reading

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Discussion

MARK HRUSKA: I would like you to comment on the unwillingness of a lot of medical examiners to entertain a diagnosis of sudden cardiac death. By that, I mean when you have a situation where somebody does not really have a lot of pathological evidence that really rules it in, but the surrounding circumstances of the death do not allow for any other conclusion; but in our experience they always put down drowning even though it is clear that the person was, say, at the surface conscious and then just slumps over and that is it. I know that you have spoken probably with Tom Newman about that. He is willing to make that kind of diagnosis, but most of the medical examiners just will not do it.

DR. JAMES CARUSO: I would agree with you, there is some stubbornness. Cardiac arrhythmia is an actual cause of death. A study by a group of Brazilian scientists a few years back looked at the long QT syndrome and whether some of the cases that were signed out as drowning might have been a result of a long QT syndrome that had been previously undiagnosed. I will agree with you, there is some reluctance in the medical examiner community. I think forensic pathologists as a rule like to have clean causes of death. And some of them go back to the old dogma, which is hard to get changed: "Went into the water alive, dragged out of the water dead. They are wet, they are dead, must be a drowning." That is unfortunate, because certainly a cardiac event in many cases did precipitate the final outcome. Even if the final outcome is a drowning, it was a drowning due to the cardiac issue, and you do no one a service just by signing out as drowning.

DR. RICHARD SADLER: Assuming that there is gas in the arterial tree, how long will it remain detectable before you are able to do a postmortem examination?

CARUSO: Usually for at least a few days, but it depends on the condition of the remains. Unfortunately, gas is also produced by the decomposition process. Some of the gas is going to get added to. That is why I consider it an artifact in most cases but worth noting in all cases. I will do the exam appropriately, document your postmortem interval and look for gas. If it is there, great. If it is not there, great, document that. But go back to history. History is by far the most important component to a case where you are presuming air embolism to have occurred.

DR. DAVID COLVARD: I am a psychiatrist. That is the first case of definite suicide I have heard. I get contacted around the world from agencies and dive shops who wonder if they should allow a diver who is on psychiatric medicines to dive. Usually the interesting thing is they think they are going to commit suicide. I have had many contacts from divers who had depression who said it is the best they ever felt. You did not mention any psychological factors in this. Do you ever look at any of the background other than that one case that apparently was suicide?

CARUSO: We do. There probably is at least one or two others in my recollection over the last 15 years that I have entertained death being suicide. There was one gentleman who had severe end-stage liver disease. The dive professional described him as catastrophic prior to the dive. I think he went down and kept going down. Nobody ever saw him again. Perhaps that was his way to go, just narcosis and then some. It sounded like he was a chemotherapy patient, end stage at that point, who went diving. There are probably a few others out there. There is a case in the Croatian literature that a dive school classmate of mine, Capt. Petri, published where the individual supposedly stabbed himself during a dive. So we see a few. Most of the people who are on antidepressant medications probably are not actively suicidal. In fact, it has become a vitamin in some certain circles. We get calls at DAN all the time about diving on Prozac. There are probably a few well covered up suicides where the insurance maybe pays better for accidental death.