SECOND EDITION

WATER-RELATED DEATH INVESTIGATION

Practical Methods and Forensic Applications

Kevin L. Erskine
Erica J. Armstrong

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To all souls who seek to know the truth.

Erica J. Armstrong, MD

Contents

Preface

> To the living we owe respect. To the dead we owe the truth.
>
> **—Voltaire (1694–1778)**

On June 6, 1996, our department was requested to respond to one of our park areas for the report of a female found floating in the lake approximately 100 yards offshore. A jet skier had been motoring along when he found himself adjacent to her body floating face down in the water. A police boat responded to the scene, retrieved the body, and transported it to the public boat ramp facility in the area. No on-scene body assessment was conducted by any responding agencies. At that time, no responding officers had the necessary training or experience in conducting a water-related death investigation, so the officers did what they were trained to do, which included securing the scene for body recovery, obtaining any witness statements, and attempting to identify the victim in question. The divers on the scene had no other obligation than to pull the victim's lifeless body onto the rescue boat for transport to shore.

I happened to be off that day and was informed of the incident by other officers during casual conversation. This case caught my attention because it was believed to be a homicide. Several people involved in the body recovery would later tell me that they recalled seeing distinctive marks around the victim's neck, and she was found floating in the lake the very same day she went missing. These were signs of foul play not commonly found in a water-related death.

In the months following the recovery, I would soon begin to learn valuable information regarding the specialized field of water-related deaths as I began our department's own investigation into the incident. It was fascinating to me to interview the pathologist who conducted the autopsy on the victim. This fascination was enough to prompt me to begin seeking formal training in the field as well as seeking information through personal research. Many indicators of foul play were evident in the case, which I would later term "red flag indicators" of foul play. The case was ultimately ruled as a suicide by a neighboring agency, and I was ordered to cease my investigation.

The intent is not to find fault in those who participated in this recovery and investigation but rather to learn from our mistakes and move on in the hope of not making those same mistakes again. Responding personnel who possess even the basic knowledge of what to look for at the scene can boost the investigation drastically by assisting the pathologist in determining time, cause, and manner of death.

What is a water-related death? Those cases of two people swimming together at the beach and one frantically runs up to a lifeguard claiming the other was overcome by waves and his or her head was submerged. A group of fishermen in a boat in the middle of a lake suddenly returns one man short, and the others claim he fell in trying to untangle his line from the boat propeller, or an elderly lady sight-seeing along a scenic trail "accidentally" slips in and was overcome by the current. These are all cases of water-related deaths. But are they truly accidents? Is a body found near a body of water still regarded as a water-related death? Without knowing what to look for on the scene, this is difficult to determine.

All too often, police called to the scene of a drowning may consider it an accident before they even arrive. Their sense of pity for the family is overwhelming, and they may even have siblings or children the same age as those involved. Our culture almost always perceives drowning as an accident. Responding officers often feel helpless due to the lack of a specially trained dive team, responsibilities of controlling on-lookers, family members' presence, and obtaining witness statements. Complicating matters further, the officer may be required to give a death notification on the scene to any family members.

An added problem is that drowning is one of the most difficult causes of death to determine. Drowning as a cause of death is determined only after a meticulous examination with a complete autopsy and after all other causes of death are ruled out. Furthermore, to rule a drowning a homicidal act is extremely difficult, mainly because it is difficult to overcome that preconceived belief that all drowning incidents are an accident. At the scene of a homicide, foul play is usually obvious, but a drowning incident is regarded as an accident because the majority of road officers do not possess the specialized training needed to process the scene properly. Larger departments have a heavy caseload, and "accidents" allow them to move forward with higher-profile cases. Likewise, smaller departments do not have the extra manpower necessary to conduct a proper follow-up. More investigative work is typically done at the scene of a motor vehicle accident than is done for a pool, tub, or open water death. To rule out foul play, it must first be considered.

During the Susan Smith case, Sheriff Howard Wells stated that there was such an outpouring of sympathy from the public that no one wanted to believe a mother could have murdered her own children by strapping them into their car seats and driving her vehicle into the lake. This statement reinforces the belief that the death must have happened another way.

A new form of recreational sex has hit society in the form of erotic drowning. Individuals, both men and women, gain sexual gratification and excitement from submersion in water. Subjects hold their partner's head under water during various sexual acts to heighten orgasm. How easy would it be to pass this off as an accident? A thorough investigation is warranted.

In ancient history, dunking was used frequently as a form of punishment. This form of water torture was common in many cultures and even used as a form of execution. Even in the Bible, Book of Genesis, God created the Great Flood to cleanse the earth and serve as the ultimate punishment for all mankind.

Sudden deaths in infants initially suspected upon scene visitation as sudden infant death syndrome (SIDS) or sudden unexpected infant death (SUID) have later been found at autopsy to have resulted from shaking with impact (nonaccidental head injury) or blunt force trauma to the trunk. In these cases, homicidal violence initially may not have been considered due to the lack of visible injury. Does this also hold true with drowning incidents? Historically, many water-related cases have been ruled accidental only to have additional information or evidence obtained months or even years later. In retrospect, investigators cannot go back and collect evidence and conduct interviews with witnesses or potential suspects. All evidence is lost, requiring investigators to learn from their mistakes, which may ultimately affect the credibility of the agency involved.

This book will cover, in part, red flag indicators of foul play. Such indicators may more accurately lead the investigator to believe that this tragic incident was in fact not an accident, but possibly an intentional act, whether by suicidal or homicidal means. These indicators will help steer the course of the investigation. Moreover, water-related death investigation does not end with the scene. The coroner or medical examiner is charged with the determination of not only why the person died but by what means and under what circumstances. This book will additionally cover the processes involved in the medicolegal death investigation of water-related deaths and stress the importance of correlation of the investigative and scene findings with findings generated by complete autopsy performance, including laboratory testing.

Kevin L. Erskine
Master Water-Related Death Investigator, Retired

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Kevin L. Erskine (Retired)

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Erica J. Armstrong, MD

About the Authors

Kevin L. Erskine graduated from Hocking College in 1982 with an associate's degree in natural resources law enforcement. He also obtained mountain rescue, search and rescue, and EMT certifications. He began his career with the Ohio State Park Police in 1986 and developed the only State of Ohio dive team in 1998. In 2000, he codeveloped the Children's Ice Drowning Prevention Workshop, which teaches children self-rescue techniques in the event of an ice accident. He designed a multiagency training scenario for an airplane crash in Lake Erie. Within months of the training scenario, an actual plane crash occurred within a quarter-mile of the training site. In 2005, he developed the Master Water Death Investigator curriculum for the Ohio Peace Officer's Training Academy (OPOTA). He is an OPOTA-certified Master Criminal Investigator who has earned numerous life-saving awards for rescues of drowning victims in the waters of Lake Erie. He was recognized as "Citizen of the Year" by the Cleveland Fire Department in 2006 for the rescue of an active drowning victim within his jurisdictional waters. He has attended police diver symposiums in Hamilton, Ontario, Canada; West Point; and Indianapolis. In 2011, he retired after 25 years of service to the State of Ohio. He currently serves as the training coordinator for Hope Christian Church First Responder Team in Avon, Ohio, where he lives with his wife and two sons.

Erica J. Armstrong, MD is a forensic pathologist and deputy medical examiner at the Cuyahoga County Medical Examiner's Office (CCMEO) in Cleveland, Ohio. She is a graduate of Case Western Reserve University School of Medicine. She completed her training in anatomic and clinical pathology at the University Hospitals Cleveland Medical Center-Institute of Pathology. She completed her training in forensic pathology at CCMEO from 2000 to 2002 under the mentorship of former Cuyahoga County Coroner Dr. Elizabeth K. Balraj and the late Deputy Chief Coroner Dr. Robert C. Challener. She is the Director of Medical Education at CCMEO and utilizes the position to provide a comprehensive educational experience to visiting medical students, medical residents, allied health students, and other students and professionals with a connection to medicolegal death investigation. She holds academic appointments at medical and osteopathic schools. She is author and coauthor of several journal articles on the topics of forensic pathology, forensic toxicology, anatomic and clinical pathology, and the biological sciences. She has authored a textbook on the topic of death reporting and death certification and maintains an educational blogsite on this subject matter.

Introduction

1

ERICA J. ARMSTRONG

Drowning: A Diagnosis of Exclusion

Deaths due to drowning and other water-related deaths remain both a local and worldwide problem with far-reaching human and economic consequences, prompting ongoing data collection, analysis, and research. A number of task forces made up of experts involved in water safety from around the world were established in 1997 in order to define recommendations and reduce the number of drowning victims and improve the outcome of casualties. These recommendations were discussed during a number of meetings held at the World Congress on Drowning in Amsterdam in 2002. A definition of drowning has been adopted and recommended for widespread use by the World Congress on Drowning, which defines drowning as "the process of experiencing respiratory impairment from submersion/immersion in liquid."[1] *Merriam Webster's Collegiate Dictionary* describes "to drown" in part as "to suffocate by submersion, esp. in water."[2] *Dorland's Illustrated Medical Dictionary* defines "drowning" as "suffocation and death resulting from filling of the lungs with water or other substance or fluid, so that gas exchange becomes impossible."[3] Drowning does not always end in fatality and can be non-fatal whereby the victim is resuscitated and recovers but may suffer medical complications as a result of lung damage, also known as secondary drowning.[3] Forensic pathologists, who are involved in the determination of cause and manner of death, generally define drowning as an asphyxial death in which the body is deprived of oxygen as a result of impairment of oxygen exchange ultimately within the lungs after partial or complete submersion in a liquid, usually water, with subsequent inhalation of some quantity of the liquid deep into the airways of the lungs. Partial or complete *submersion* specifically involves partial or complete coverage of the external airways (nose and mouth). All of the above definitions have in common that drowning involves a compromise of respiratory function that if prolonged, can result in irreversible neurological and organ injury or death. Death may occur acutely within minutes and upward of 24 hours after submersion, or may be delayed beyond 24 hours, in which the victim can develop a number of medical complications arising from direct lung injury by the inhaled fluid or water or oxygen deprivation. This delayed death is also referred to as **near drowning** by forensic pathologists while the World Congress on Drowning uses the terminology to refer to victims who survive the drowning event. Forensic pathologists consider the determination of death due to drowning as a diagnosis made by the exclusion of other potential causes of death by the performance of a complete autopsy with a review of medical records, test results, and all investigative and scene information. While there are a number of autopsy findings *supportive* of drowning, there is no one definitive test or autopsy finding that can absolutely unequivocally define drowning, and not all individuals recovered from a body of water can be presumed to have drowned.

Bodies recovered from water are often prematurely labeled as accidental drownings; however, a significant number of drownings and other water-related deaths occur as a result of natural disease or by homicidal, suicidal, or undetermined means. For those who are involved in the investigation of drowning deaths, this is important to recognize in order to maintain an open mind and not overlook clues that may indicate circumstances other than accidental. The cause of death of an individual recovered from a body of water may actually be as a result of natural diseases, such as heart disease that causes collapse and death prior to, upon, or during submersion (i.e., while swimming). While the scene investigation suggests that the individual has accidentally drowned, the autopsy findings may show complete blockage of a coronary artery with damage to the heart muscle supplied by that blocked artery, with very little or lack of supportive findings of drowning. More importantly, while the scene where an individual recovered from a body of water may appear accidental in nature, the individual may have expired prior to submersion or upon submersion from injury or intoxication by illicit drugs or prescription medications. Accidental injury prior to or upon submersion (i.e., impact on rocks or impact with the bottom of a pool) may alone result in death or contribute to drowning. In other words, the individual is made more susceptible to drowning with the addition of an incapacitating injury.

Fatal drowning may occur passively after an attempted revival by immersion in cold bathwater of an individual who is suspected to have taken an overdose of illicit drugs or prescription medications. Death may also result from the overdose or intoxication alone, just prior to passive submersion from slumping over or collapsing into the body of water. In this case, the performance of comprehensive toxicological testing in addition to a complete autopsy and review of all investigative information is essential for the proper determination of the cause of death and the manner in which the death came to be (i.e., accidental manner of death solely by an acute overdose/intoxication *or* by drowning during or as result of an overdose/intoxication). Because the autopsy findings of drowning and overdose are often similar, it may be difficult to clearly identify which was actually the cause of death.

In some cases, the determination of drowning as the cause of death is certain; however, the manner in which the death came to be is uncertain or cannot be determined. Take, for example, an individual with a debilitating neurological disorder such as multiple sclerosis who had prior to her untimely death voiced to an acquaintance her frustration and sadness with coping with her worsening condition. She was found submerged in 3 feet of debris-filled water near the shoreline of a lake in the late spring. She was accompanied by her acquaintance, who did not witness the event, reportedly due to being turned away from her during the moments leading up to submersion. There are no other witnesses. Her walking cane, which she always used by necessity, is not recovered and is otherwise not found. Autopsy findings are supportive of drowning and specific for multiple sclerosis. There are no other significant injuries, including injuries consistent with homicidal violence. Results of toxicological testing are noncontributory. The **cause of death**, defined as the injury or disease leading to death, most probably is drowning. The difficulty for the forensic pathologist, in this case, is in determining how the death came to be—the **manner of death**. Did the acquaintance push her in, leaving no marks of injury? Did she bid "farewell" and simply just walk over the edge of the pier into the lake as the acquaintance tried to restrain her from taking her life? Did she venture too close to the edge and, because of the unsteadiness caused by her illness, slip and fall in? When there is insufficient information to allow for the categorization into one of the four main categories for the manner of death (**natural**, **accident**, **suicide**, or **homicide**), the death is ruled as "undetermined" and the cause and manner of death are entered onto the death certificate. Should additional information or evidence arise at a later time (i.e., a confession from the acquaintance that after a heated argument he took her cane from her and pushed her in), the death certificate may be amended with a change in the categorization for the manner of death (i.e., from "undetermined" to "homicide").

Identification of any body recovered from a body of water such as a lake, river, or ocean is of primary importance. The determination as to whether badly decomposed remains, whole or partial, are even human may be the first task to complete, and the condition of those remains could potentially preclude subsequent identification. Nevertheless, knowledge of the decedent's identity may not only assist the investigator in uncovering the circumstances surrounding the death, but also bring to light information about the decedent's medical and psychiatric history, lifestyle, and swimming ability. Knowledge of medical and psychiatric history may be the key to deciding whether natural disease or death by suicide precipitated by a psychiatric condition played a part. Without this information, and with a lack of definitive autopsy findings supportive of drowning or another cause of death, the determination as to the cause and manner of death may both be designated as undetermined. In one previous study, it was found that among the unidentified individuals in a series of 123 drowning deaths, 97% were certified as undetermined manner of death, compared to 25% in the identified group. Of the unidentified deaths without mechanical trauma, 30% were certified with an undetermined *cause* of death compared to only 5% in the identified group.[4]

Individuals recovered from water cannot automatically be presumed to have drowned accidentally. Individuals killed by other means, such as strangulation, sharp force injury, or blunt force injury, may be disposed of in water in the hopes that the body may not be recovered or recovered only after the onset of extensive decomposition, rendering identification and the determination of the cause of death difficult or impossible. In the case of an individual who cannot be readily identified, the most important task for both the investigator and the forensic pathologist obviously is to establish the identity. Identification can not only facilitate the investigation into the circumstances surrounding the death, but can also serve the purposes of providing notification to the family and the proper certification of death for the correct individual. Collection and preservation of evidence with the performance of a complete autopsy should quickly commence and are essential pieces of the puzzle within the whole realm of investigation of water-related deaths, particularly those of suspicious nature. Moreover, an individual may have been killed and then placed into a body of water to make it appear as if he or she drowned, with the addition of an elaborate or inconsistent story told by the perpetrator(s) or accomplice(s) as to how the decedent "accidentally" drowned: the so-called *staged drowning*. The autopsy may disclose recent injury in a pattern consistent with suffocation, strangulation, and other homicidal blunt and sharp force injuries inflicted prior to submersion. Homicidal violence must also be considered, particularly in suspicious drownings involving not only adults, but the more vulnerable members of our society, namely infants, children, the physically disabled, and the elderly.

The investigation of bodies found in water requires the coordinated efforts of law enforcement, medicolegal death investigators, forensic pathologists, forensic scientists, and other ancillary scientific experts. The most accurate determination of the cause and manner of death will follow the review and correlation of all available investigative and autopsy information. As previously stated, not all bodies recovered from water can be presumed to have drowned, for a variety of important reasons, which need to be considered by all involved in this type of death investigation. The forensic pathologist knows that an autopsy alone may not provide all of the answers, including the cause of death. Furthermore, when death due to *accidental* drowning is strongly favored, one must consider whether or not certain human and environmental factors could have predisposed an individual to drowning. The late Dr. Joseph H. Davis, a well-known forensic pathologist and former Chief Medical Examiner of Miami-Dade County, referred to this as the "drowning equation," in which drowning is the constant (and end result) and certain human and environmental factors are the variables.[5] Consideration of the equation can help answer questions regarding how and why the individual became submerged and why the individual was unable to self-extricate. The investigation may uncover aspects of the medical or social history or certain hazards of the environment. The autopsy can confirm known aspects of the medical history or uncover a totally unexpected finding that either predisposed the individual to drowning or in and of itself caused the death of the individual, who happened to have been in the water at the time of death. The findings from toxicological testing on body fluids recovered at autopsy may confirm that an individual was in fact overdosing prior to and during submersion which then led to the drowning. Finally, consideration of the components of the drowning equation may help in the differentiation between unintentional/accidental and intentional (suicidal or homicidal) drownings. Lack of predisposing human factors and problems with the environment should bring to mind other possible causes and prompt additional inquiry and investigation.

Drowning Statistics and Epidemiology

Globally, unintentional (accidental) drowning remains a significant public health concern prompting ongoing research regarding where, how, and why these deaths occur in order to prevent future deaths. The World Health Organization (WHO) collects, compares, and reports injury and mortality data provided by participating countries. Specifically, the Violence and Injury Prevention and Disability Department of WHO is charged with raising awareness regarding the degree and consequences of injuries, violence, and disability through the collection, analysis, and dissemination of injury- and disability-related data in order to improve health services, foster research, prevent injuries and death.

As of 2015, an estimated 360,000 deaths were due to drowning, making it the third leading cause of unintentional injury death globally, after road traffic accidents and falls, and represents 7% of all injury-related deaths.[6] The more current figure excludes deaths due to cataclysmic events such as floods and transportation accidents, thereby underestimating the true number of drowning deaths. Moreover, distinctions between unintentional and intentional drowning deaths (i.e., suicides and assaults) are unclear, since some may not be reported or may be misclassified. The majority of drowning deaths occur in low- and middle-income countries within the Western Pacific, Southeast Asian, and African regions.[6] Among age groups, children five years of age and younger have the highest drowning mortality rates globally.[6] Within the United States and Australia, drowning mortality rates were higher among the indigenous populations than the white population.[6] The fact sheet also cites an extensive list of major risk factors for drowning. Those factors notably include male sex, young age, water-related occupation, weather extremes, unsafe boats, lack of boating safety equipment, alcohol impairment, low socioeconomic status, and access to unsafe/unsecured water environments.

In the United States, the magnitude and distribution of drowning deaths parallel those noted globally, including age- and sex-related risk factors and socioeconomic status. Between 1999 and 2017, a total of 66,805 unintentional (accidental) drowning deaths (excluding transportation-associated incidents) were recorded. In 2017 alone, there were a total of 4,508 deaths due to drowning by unintentional (accidental), homicidal, suicidal, and undetermined intents, for all ages and races, and for both sexes: 3,709 deaths were accidental, 35 homicidal, 479 suicidal, and 285 undetermined.[7] Death by drowning ranks fifth among the leading causes of unintentional deaths. [7]

According to the CDC "Water-Related Injuries Fact Sheet," in 2005, for unintentional drownings occurring within the United States, men, children, and minorities were most at risk.[8] Drowning in infancy and childhood remains the second-most common cause of accidental death in recreational settings.[9] Analysis of these deaths has revealed a number of risk factors. Lack of barriers around sites containing water (bathtubs, buckets, toilets, and swimming pools) and lack of supervision of young children who have access to these sites are noted. Recreational and natural water settings such as lakes, rivers, and oceans are the common locations for drowning in individuals greater than 15 years of age. The lack of adherence to safety measures, including the use of approved flotation safety devices while boating or proper use and operation of personal watercraft, constitutes another risk factor for not only direct drowning deaths but also water-associated deaths due to trauma, hypothermia, and carbon monoxide poisoning. Alcohol intoxication, which is known to affect motor skills and judgment, was found to be yet another significant risk factor associated with water recreation and boating. Underlying medical conditions such as seizure disorders also confer risk. Individuals with seizure disorders are at an even higher risk of drowning, with the bathtub as the site with the highest drowning risk.[8]

Preventative measures have been proposed by various national, international, and global study groups in order to reduce the number of risk factors and thus the risk for injury or death. These include providing barriers and fencing to pools and small natural bodies of water, discouraging alcohol consumption during water recreation, promoting swimming and cardiopulmonary resuscitation education, and promoting the use of approved flotation devices.

The Drowning Process

Respiratory (Pulmonary) Physiology

The human respiratory system conveys oxygen-containing air into the body via inhalation and is comprised of the nasal and oral passages, larynx, trachea, bronchial tubes, and lungs (Figures 1.1 and 1.2A and B). The flexible and tubular larynx, trachea, and bronchial tubes are kept open or patent by rings of cartilage allowing unobstructed movement of oxygen-containing air into the lungs with inhalation and carbon dioxide waste products out of the lungs and body upon exhalation. The cells lining the airways have microscopic hairs and produce mucous which along with the cough reflex help trap particulate matter and bacteria and keep the airways free and clear of obstruction. The nerves of the larynx also sense pressure caused by the inhalation of foreign objects including fluids and can trigger brief closure or spasm, known as **laryngospasm**, as an additional protective mechanism to prevent obstruction of the airway and further interference with oxygenation. The skeletal muscles between the ribs (intercostal muscles), and the skeletal muscles attached

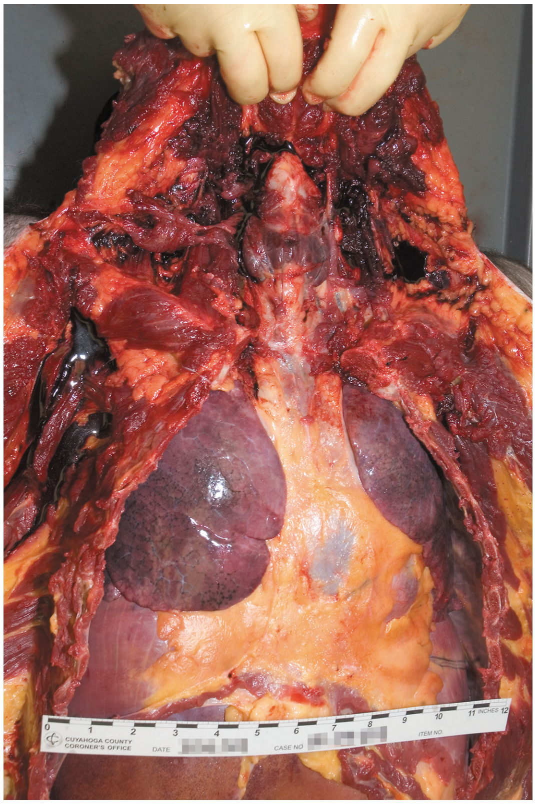

Figure 1.1 Gross anatomic photograph of the trachea, larynx, and lungs *in situ*.

(a) (b)

Figure 1.2 A and B (A) Gross anatomic photograph of lungs with attached trachea and right and left bronchial tubes and heart (posterior view) and (B) Gross anatomic photograph of lungs with attached trachea and right and left bronchial tubes, featuring rings of cartilage supporting trachea and bronchial tubes (posterior view).

to the sternum, the diaphragm, and the abdominal muscles are all important structures in respiration, as they work to expand and contract the rib cage during inspiration and expiration of air (Figure 1.3).

Respiration, or the process of gas exchange that occurs during **inhalation** and **exhalation**, is an involuntary process that is under the control of the central nervous system (CNS). The terms **inspiration** and **expiration** are used synonymously also to refer to

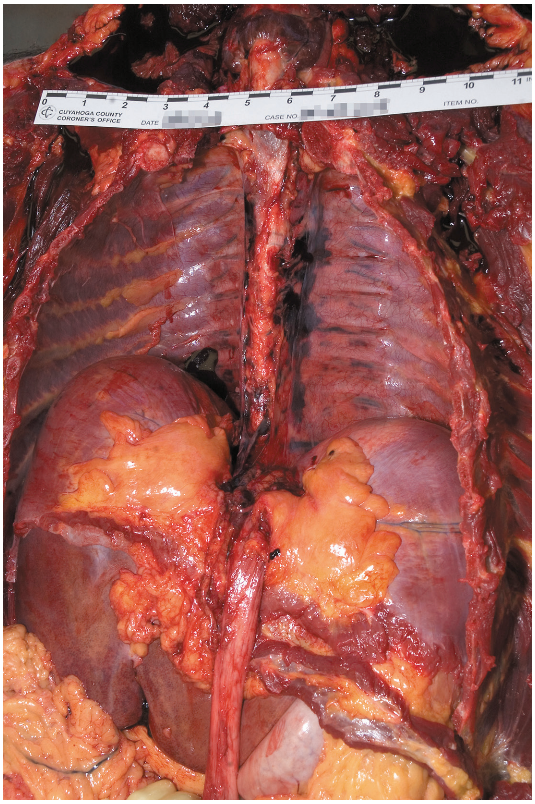

Figure 1.3 Gross anatomic photograph of the thoracic cavity after removal of the heart and lungs, featuring intercostal muscles and diaphragm.

inhalation and exhalation, respectively. The CNS senses and monitors both the body's oxygen and carbon dioxide (CO_2) levels and can moderate those levels as needed in part by controlling the rate and depth of breathing. CO_2 is a waste product of cellular metabolism and is expelled during exhalation.

The lungs are spongy elastic organs, usually pink-red in color, with each adult lung weighing normally between 325 and 570 grams, with the right lung normally slightly heavier than the left. The right lung normally has three lobes and the left lung two (Figure 1.4A and B). The blood supply to the lungs originates from the heart, which gives rise to the right and left pulmonary arteries, and from the aorta, a large vessel arising from the heart that gives rise to the bronchial arteries (Figure 1.4C). Lungs inherently have a great capacity for expansion upon the inspiration of air. They contain innumerable tiny air sacs called **alveoli**, the deepest and terminal-most parts of the airways, that arise after innumerable branching of the larger airways (bronchi and bronchioles) (Figure 1.4D). The alveoli lack the cartilaginous rings of the upper airways and would be prone to collapse, due to the forces of surface water tension, but for the presence of **surfactant**.[10] Surfactant is a natural chemical comprised of proteins, phospholipids, and ions secreted by specialized epithelial cells (**type II pneumocytes**) that line the alveoli. Surfactant reduces the surface water tension and prevents collapse of the alveoli, which if collapsed would become unavailable for O_2–CO_2 exchange. The alveoli are adjacent to tiny blood vessels or **pulmonary capillaries**. Capillaries

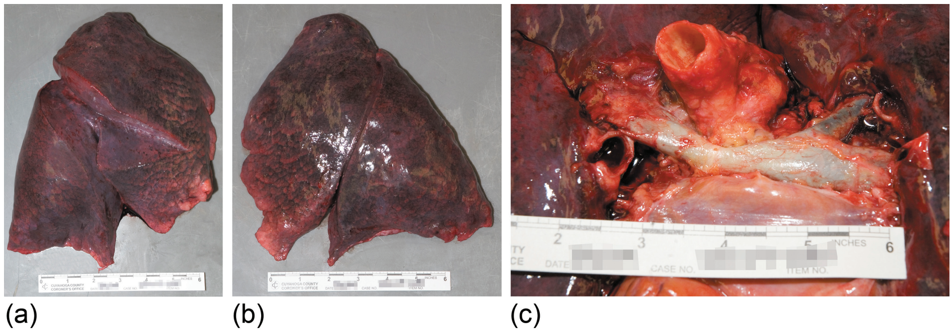

Figure 1.4 A–D (A) Gross anatomic photograph of right lung with three lobes, (B) Gross anatomic photograph of left lung with two lobes, (C) Gross anatomic photograph of posterior view of lungs with heart, and (D) Gross anatomic photograph, close-up view of cut surface of lung, featuring numerous tiny air sacs (alveoli) in lung with mild emphysema.

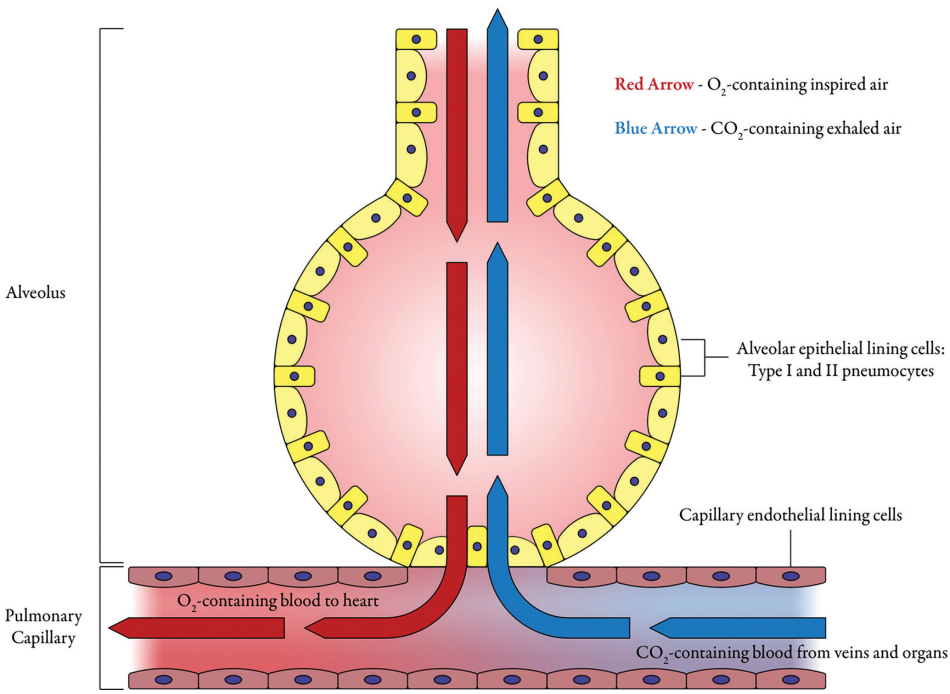

Figure 1.5 Illustration of the alveolar-capillary interface and movement of O_2 and CO_2 in alveolar ventilation.

are low-pressure conduits that connect blood flow from the veins to the arteries. The alveolar-capillary interface is the site of O_2 and CO_2 exchange, also known as **alveolar ventilation**[10] (Figure 1.5). With inspiration, O_2-containing air is brought in and down into the alveoli with the diffusion of O_2 into the pulmonary capillaries, where it circulates attached to red blood cells back to the heart, which pumps the oxygen-rich blood to the rest of the organs via the arteries. CO_2, collected and circulated by the veins from all of the organs to the heart and subsequently the lungs, diffuses from the blood within the pulmonary capillaries into the alveoli and is conveyed out of the airways during exhalation (Figure 1.5).

Pathophysiological Effects of Drowning

Our current knowledge of the effects of drowning in watery environments is a result of prior clinical observation of hospitalized human victims, experiments performed on human volunteers, animal experiments, and findings of postmortem (autopsy) examinations. Drowning occurs as a result of prolonged submersion in a liquid such as water with the gradual reduction in the blood and tissue/organ oxygen levels, leading to abnormal physiological states (also known as pathophysiological). These importantly include **hypoxemia** and **hypoxia**, respectively, which can lead to cardiopulmonary arrest and eventually death if not treated. Oxygen (O_2) is an odorless gas produced from water by certain bacteria, algae, and plants by the process of photosynthesis and released into the atmosphere. The normal percentage of oxygen in the atmosphere is approximately 21%. It is essential for the life of countless organisms, both seen and unseen. Within the human body, O_2 binds with the red blood cell protein **hemoglobin** and is carried by the red blood cells within the blood circulation and delivered to the tissues and organs. Within the cells that comprise the organs, oxygen is used to produce energy for the maintenance of normal cellular functions, and thus tissue and organ function. **Neurons** are cells found in the brain that control many functions of the body. Certain regions of the brain contain neurons that are especially sensitive to reduced or absent oxygen states **(hypoxia** or **anoxia)** and can become irreversibly damaged or die, thus compromising brain functions including those that control cardiac and respiratory functions. Irreversible neuronal cell damage may begin approximately four to six minutes after sustained O_2 deprivation, and the degree of functional recovery is dependent on the extent of the irreversible brain damage and the promptness of resuscitation efforts. In drowning, the exchange of inspired oxygen is impaired deep within the lungs by the presence of inhaled fluid and sometimes debris, preventing the gas from entering the bloodstream and being circulated to the organs, including the brain (Figure 1.6). Cells deprived of oxygen switch to an alternative pathway

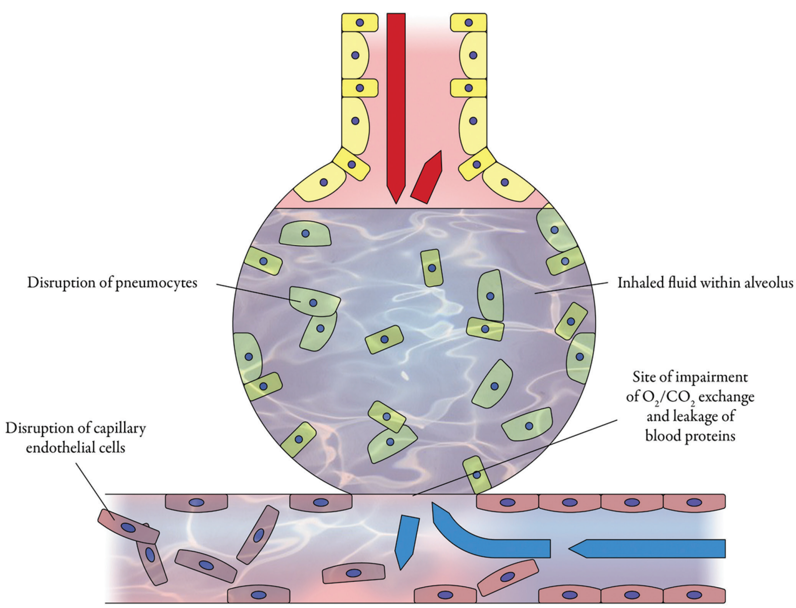

Figure 1.6 Illustration of the alveolar-capillary interface featuring disruption of the alveolar and capillary lining cells with impairment of O_2–CO_2 exchange and inhalation of fluid during drowning.

of energy production with the generation of acid, which enters and circulates within the bloodstream. In addition, CO_2 builds up in the blood. The combination of increased acid and CO_2 leads to a pathophysiologic change called **metabolic acidosis**, which is measured clinically in near-drowning patients by the analysis of arterial blood for levels of certain metabolic products and pH. The volumes of inhaled fluid causing these pathophysiologic effects may be relatively small, and the lungs do not necessarily need to be completely filled with inhaled fluid.

Individuals who are resuscitated and hospitalized following a submersion event may fully recover, expire, or develop a number of complications triggered by the inhalation of water. In forensic pathology practice the phrase **near-drowning** has been used on death certificates to refer to an individual who expires after the development of certain complications despite the administration of therapy, within a day but as long as days or even weeks of survival. Clinical complications, ones that may be lethal, include anoxic-ischemic encephalopathy (brain dysfunction resulting from low or absent O_2, respiratory failure), cerebral edema (brain swelling), pulmonary edema (lung fluid), pneumonia (lung inflammation and infection), **acute respiratory distress syndrome** (**ARDS**), sepsis (widespread bacterial infection and/or multiorgan dysfunction), and multiple system organ failure. Particularly, ARDS can arise as a result of direct lung injury by inhaled fluid or aspiration of gastric contents with subsequent development of aspiration pneumonia. Other also potentially lethal complications include a rapid breakdown of the muscles (rhabdomyolysis) and metabolic acidosis which can have adverse effects on multiple organ systems leading to multiple system organ failures and abnormal blood clotting **(disseminated intravascular coagulation** (**DIC**) if not reversed.

Post-immersion syndrome, also referred to as **secondary drowning**, is another potentially lethal complication in which the lasting damaging effects of water inhalation and the insufficient production of surfactant causes deterioration of respiratory function and the need to be re-hospitalized. [13]

The Process of Drowning

Prior experiments on submerged awake dogs (ethically inappropriate by today's standards) have reported five phases of drowning, lasting a total of 3½–4 minutes:[11–13]

- Nonpurposeful then purposeful movements, first five to six seconds
- Mouth closure, no respiratory movements, lasting one minute
- Profound respiratory movements, foam on water surface, gradual cessation of movements, lasting one minute
- Arrest of circulation, immobile thorax, dilated pupils, and lack of corneal reflex, lasting one minute
- Three or four respiratory movements and no further evidence of life

In humans, drowning can take place in as little as a few inches of water, which may be encountered in puddles, streams, bathtubs, and buckets. Thus the submersion of the face with the involvement of the entry points to the airway (nose and/or mouth) rather than the entire body is the main focus. Children, intoxicated individuals, individuals with seizure disorders, injured individuals, and those with physical and mental disabilities are particularly at risk for drowning at any depth, but especially in shallower bodies of water.

The process of drowning encompasses two general phases: **immersion** and **submersion**. Immersion involves the initial contact of the body with the watery environment that occurs before the head along with the nose and/or mouth becomes submerged. During the immersion phase, one or more factors that ultimately precipitate the drowning process may be at play.[14] These include environmental factors inherent to the watery environment such as temperature extremes (particularly cold water) and strong currents. Additionally, human factors, such as panic, fear, swim inability, drug and alcohol impairment, physical disability, physical injury, and whether the face is the first point of contact with the water versus the rest of the body, may each or in combination be at play. The wrong combination of certain human and environmental factors may put even the experienced swimmer at an increased risk of drowning.

The sequence in the process of drowning in humans, particularly in deeper bodies of water, has some similarities to that described in animal experiments.[11–14] Following the immersion phase and upon initial submersion of the head into the water, there is a period of voluntary breath-holding (apnea) as the victim struggles to maintain the position of the nose and mouth above the surface of the water. Psychological factors such as panic and fear may also be at play at this point. The length of the apnea period is variable and based on many factors such as physiological tolerance, swim and diving experience, psychological factors, and environmental factors (particularly water temperature extremes). As breath-holding continues, the CO_2 will continue to rise along with the fall of O_2 to critical levels referred to as the **break-point**. All organs are vulnerable to lowering O_2 and CO_2 levels but the brain is especially sensitive. Upon reaching the break-point, the urge to breathe causes involuntary gasping. At this point, if the swimmer has become fatigued and is no longer able to maintain the face above water, gasping with inhalation of water (along with any debris) instead of air will result. The amount of water inhaled varies between individuals and need not be great. [11] During this time, a brief spasm of the upper airway (laryngospasm and bronchospasm) may occur triggered by the inhaled water but whether or not this prevents water from getting into the lungs has been a subject of debate. Eventually, with the worsening hypoxia, the spasming will cease allowing entry of water. Also during the period of inhalation, large quantities of water may be swallowed, and vomiting with the aspiration of acidic gastric contents into the lungs can occur simultaneously, which can lead to further lung damage. The asphyxial nature of drowning and the resultant brain hypoxia causes loss of consciousness simultaneously or shortly after inhalation of water. Lowered brain oxygen as a result of continued submersion will lead to the development of seizures, respiratory failure, and arrest, and after a period of several more minutes of continued heart activity, cardiac arrest. The development of an abnormal heart rhythm (arrhythmia) leading to cardiac arrest can occur at any time during the drowning process. Involuntary loss of urine, feces, and seminal fluid may also occur during the drowning process. In the terminal, near-death period (also referred to as agonal), spontaneous respiratory efforts occur and may permit further penetration of the fluid into the lungs in addition to the fluids that have already been inhaled or have formed as a result of the physiological responses to the drowning, mainly pulmonary edema. [14] It is currently not possible to determine the proportion of fluid that was inhaled versus the fluid that was produced as a result of the physiological response to the drowning. [14]

The development of hypoxemia with hypoxia can develop within minutes. The time to death as a result of low oxygen states has been said to range from 3 to 10 minutes in water greater than 15–20°C (58–68°F).[12–14] Survivability of individuals, especially children, submerged for prolonged periods in colder water with subsequent rescue and resuscitation has been reported. [15] Even with resuscitation following prolonged submersion, irreversible damage and cell death of the most vulnerable neurons may result leading to permanent brain damage and disability. [14]

The sequence of events may be altered with deliberate hyperventilation prior to submersion, as may be practiced by individuals in order to increase endurance during diving activities. The process of hyperventilation, with the taking of several deep breaths prior to submersion and descent, can cause a significant *decrease* in CO_2 levels (bypassing the involuntary trigger that initiates breathing), with subsequent rapid drops in O_2 alveolar and blood levels upon ascent to the surface. The individual may lose consciousness due to cerebral hypoxia and spontaneously resume breathing with the inhalation of water and drowning, before reaching the surface. This phenomenon is also known as **shallow water blackout**.[16,17]

With the entry of water/fluid into the lungs, other physiological changes occur.[13] Inhalation of fluid causes laryngospasm, resistance to airflow to the terminal airways, constriction of the small pulmonary vessels, decreased lung compliance, and alteration of alveolar/pulmonary capillary gas exchange and capillary blood flow. Moreover, the presence of water (saltwater or freshwater) within the alveoli diminishes or cancels the effect of surfactant, leading to alveolar collapse. Water within the alveoli moves across the pneumocytes into the adjacent capillaries, causing disruption and damage to both the alveolar lining cells and capillary lining cells (**endothelium**). This disruption and damage allow for leakage of red blood cells and blood proteins into the alveoli (**pulmonary edema**), and with the mixture of water, surfactant, and air already within the lungs, the production of a white or blood-tinged foam will occur. This foam or froth moves into the upper airways, including the trachea and larynx, and may make its way out of the nose and mouth, forming a **foam column** or **foam cone** (Figure 1.7). The presence of the foam is nonspecific for drowning and may be seen in other types of deaths, including drug overdoses, stroke deaths, and deaths caused by certain heart and lung diseases. The presence and the degree of the foam may be reduced or made absent by resuscitative attempts, which cause the foamy fluid to flow out more rapidly. In addition, a drowned individual dead for an extended period of time (with or without obvious signs of decomposition) may present with little or no foam.

Freshwater vs. Saltwater Drowning

Whether freshwater or saltwater is inhaled, the end result of prolonged submersion in either media leads to the disruption of the alveolar-capillary membrane along with O_2/CO_2 exchange, accumulation of edema fluid within the alveoli, formation of ARDS, and lowered blood and brain O_2 levels, the effects of which have already been discussed.[14] Freshwater, which is generally hypotonic, directly alters, damages, or dilutes surfactant at its source, thereby increasing the alveolar surface tension allowing the collapse of the alveoli and impairing gas exchange, unless pulmonary edema has already developed and the alveoli are already filled up. Saltwater, which is hypertonic, rapidly draws proteinaceous fluids from the capillaries into the adjacent alveoli also damaging surfactant, impairing gas exchange, and causing pulmonary edema.[17,18] Depending on the amount and type of water inhaled, changes in blood volume and blood electrolyte levels have been reported in hospitalized drowning victims with greater changes seen when large amounts of either

Figure 1.7 Gross anatomic photograph of the foam column in an individual dead from a drug overdose.

freshwater or saltwater have been inhaled, the effects of which are not always fatal. The influx of relatively hypotonic freshwater into the alveoli, especially in large quantities, allows rapid entry of water into the blood circulation, with some increase in blood volume and decrease in the electrolyte levels as a result of dilution.[18] This increase in blood volume can strain the heart and contribute to the development of pulmonary edema or lead to the development of abnormal cardiac rhythms and death. The influx of large amounts of relatively hypertonic saltwater into the alveoli causes a rapid inflow of fluid from the blood circulation into the alveoli leading to elevated blood electrolyte levels but life-threatening changes have infrequently been reported.[18]

"Dry Drowning"

Most drownings involve some degree of water or fluid penetration into the lungs resulting in lungs of increased but variable weights, with the production foamy fluid and edema evident (to variable degrees) at autopsy and microscopically, thus representing the so-called **wet drowning**. Previous animal and clinical research studies have reported the apparent lack of inhalation of water occurring in approximately 5–15% of drownings.[11] In deaths where drowning was suspected, the lungs and upper airways lacked foam and edema suggesting the occurrence of so-called **dry drowning**. Dry drowning was thought to have occurred as a result of involuntary spasm and closure of the larynx or **laryngospasm**, with subsequent formation of a plug of mucus, foam, and froth, preventing the entry of appreciable amounts of fluid into the lungs.[11,13,19] More recent critical appraisal of the past literature alongside the examination of a large number of adult drowning victims indicate that the actual incidence of true dry drownings likely represents a very small segment of 2% or less and other causes of death including natural and other non-natural causes must be actively sought. [11,20] Whether or not the so-called dry drowning actually occurs still remains unclear and unproven prompting the World Congress on Drowning to recommend abandoning the use of the term. [1,11,14,20] Therefore the so-called dry drowning remains a controversial topic among forensic pathologists who will exercise caution before designating a death due to drowning in the absence of supportive lung findings. The absence of these supportive findings necessitates consideration and the search for other causes of death, including natural disease, intoxication/poisoning, injury, or other types of asphyxial deaths.

Drowning Tests

Since it is known that inhaled fluid can cause changes in the lungs, the blood circulation, and other organs, various tests have been developed to detect these changes as ways to diagnose drowning or determine the location of the drowning event. Despite these efforts, both past and present, there currently remains no scientifically valid, reliable tests that provide consistent and easily interpretable results in all cases. Efforts to develop such tests that are also widely available, cost-efficient, and timely are ongoing. This is particularly the case in bodies that have been submerged for prolonged periods and are badly decomposed or injured bodies where water can enter passively through wounds. Therefore currently the diagnosis of drowning as a cause of death remains one made in the context of all available historical and investigative information and supportive autopsy findings with the exclusion of other potential causes of death. More recent efforts continue in the pursuit of better diagnostic tests, however.

Historically, tests for ocular (vitreous humor) fluid electrolytes and magnesium ions and the Gettler serum chloride test on ventricular heart blood were devised in attempts to diagnose drowning or differentiate freshwater from saltwater drowning.[19,20] Other tests attempted to measure the specific gravity differences in blood taken from the cardiac chambers in order to diagnose and differentiate freshwater from saltwater drowning with inconsistent and unreliable results. More recently, the analysis of ocular fluid has been shown to be potentially useful in distinguishing freshwater and saltwater drowning by measuring the sodium level. [21]

Diatoms are the microscopic skeletons of single-celled algae-type organisms that are widespread and found in air, soil, and natural bodies of water, including freshwater, saltwater, and brackish water. They have been used to assist in aquatic crime scene investigation by the method known as **forensic limnology**.[22] During the drowning process, diatoms gain entry into the circulatory system, tissues, and organs through the disrupted alveolar-capillary membrane, and thus their identification in human tissues has been used as a supportive or definitive evidence of drowning. Diatoms may also gain entry into the body in non-drowning instances such as through breathing in air or dust or aspirating drinking water. Postmortem passive entry into the internal organs during prolonged submersion with the onset of decomposition, during resuscitation efforts, and during the preparation of the tissue sample for testing are potential sources of contamination that have been identified as giving rise to false-positive test results that were interpreted as drowning when no such drowning had occurred. [23]

The unique species-specific structures and size characteristics of diatoms have been used to differentiate freshwater drowning from domestic water drowning.[23] Extraction and analysis for the presence, characteristics, and density of the diatoms have been performed on a variety of tissue samples, although bone marrow and lung tissue are the preferred specimens. Results of tissue analysis have been compared to the results of the analysis on the water from which the individual was recovered to aid in the diagnosis of drowning and the determination of the location of drowning. [23] Due to the widespread occurrence of diatoms, however, their presence in non-drowned individuals, and the propensity to be retained within the body indefinitely, the controversy remains regarding the interpretation of results and usefulness in the diagnosis of drowning and the location of drowning.[19,21,23]

The perfect test remains elusive and efforts through research and development of better, faster, more reliable, and more accurate diatom tests that can be applied to a variety of tissues and bodily fluids (i.e., lung, liver, kidney, bone marrow, and cavity fluid) in conjunction with drowning media are ongoing. [24, 25, 26]

Scientists continue their efforts through research to identify other methods to assist in the diagnosis of drowning or drowning location. The detection of certain bacteria common in certain natural aquatic environments from drowned bodies may aid in the determination of drowning as a cause of death.[27] The detection of elevated levels of the trace element strontium in the blood of drowning victims has been shown to be highly sensitive for freshwater and seawater drowning.[19,28] A fairly recent study has shown differences in the production of surfactant proteins in drowning deaths as compared to other types of deaths using human lung tissue. [29] Differences in the electrolyte concentration in pleural effusion fluid as well as the detection of the presence or absence of marine bacteria have been used to differentiate between freshwater and seawater drownings.[30–32] The suppression in the genetic expression of aquaporin-5 (AQP5) by Type I alveolar epithelial cells (Type I pneumocytes) has been demonstrated in the lungs from the victims of freshwater drowning.[33] The application of imaging techniques such as the whole body computed tomography (WBCT) has shown usefulness in the non-invasive workup of drowning deaths with the finding of excess fluids and sedimentary debris in the sinuses and cavities of the head and chest, mouth, lungs, and the gastrointestinal tract. [34] WBCT has also demonstrated changes in the spleen of freshwater drowning victims indicative of dilution of the blood as a result of the drowning process. [34]

Even without the performance of such specialized tests, which may be further limited by availability, budget, and technical feasibility, a general microscopic comparison of the overall characteristics of various debris that may be identified within the lung tissue and stomach contents of a drowning victim to a sample of the water or fluid from which the victim was recovered (the medium) can still be done. This comparison may be helpful in confirming or refuting the location from which the victim was recovered. It is perhaps conceivable that chromatographic-mass spectrophotometric and scanning electron microscopic technologies utilized in toxicology and trace evidence labs, respectively, could also be applied to water or fluid samples that may contain chemicals and unknown substances for the purpose of identifying them and determining or confirming their origins.

Cold-Water-Related Deaths

The physiological responses to cold water immersion put one at particular risk of drowning. [14] Prolonged contact with water at a temperature between approximately 25°C (77 °F) and 15°C (59 °F) is sufficient to trigger these responses that are divided into four stages: skin cooling or **cold shock**, cooling of superficial nerves and muscle, cooling of deep tissues, and post-immersion collapse. [35] With prolonged submersion in cool or cold water, cooling of the deep tissues leading to **hypothermia** results. Even with rescue and resuscitation, the physiological effects of hypothermia alone (with or without the effects of drowning) may persist leading to the decreased function of multiple organ systems and ultimately cardiovascular collapse and death and is known as **post-immersion collapse**. Death may result from drowning at any of the stages, from cardiac arrest, or as a result of the effects of hypothermia.

After a fall into cool or cold water with the cold shock response (the first stage), the initial breath-holding response is rapidly overcome by involuntary gasping and hyperventilation which, if the head is underwater, will lead to water inhalation triggering the drowning process. With face-first cool or cold water immersion, not only will the gasp reflex be triggered but also the dive reflex simultaneously. The **diving reflex** (also known as the **diving response** or **mammalian diving reflex**) is an involuntary reflex triggered by face-first immersion that causes activation of the autonomic part of the nervous system. It is prominent in diving mammals, reptiles, and human infants and children. The ultimate effect of this reflex is the conservation of O_2 by slowing its consumption via reducing the heart rate (bradycardia), constricting the blood vessels and raising the blood pressure (hypertension), and causing the O_2-containing blood flow to shift from the skin, extremities, and other organs to the brain which needs it the most. While the dive reflex activates the autonomic part of the nervous system, the effects of the cold shock response activate the sympathetic part of the nervous system. This causes an increase in heart rate (tachycardia). The activation of these two opposing parts of the nervous system creates what is known as the **autonomic conflict** and represents a perilous time in which the spontaneous development of abnormal and potentially lethal heart rhythms (arrhythmias or dysrhythmias) can occur.[14] Individuals who have an underlying genetic predisposition to arrhythmias or heart disease may especially be at risk for the development of arrhythmias. These abnormal heart rhythms may also occur even before the point of autonomic conflict, in the first few seconds following submersion and after the breath-holding period is overcome by cold shock. Arrhythmias that follow cold water submersion can result in absence of water inhalation (drowning) and would not be detectable by autopsy examination of the heart. Moreover, the spontaneous gasping movements in the last moments of the drowning process may allow water to enter into the lungs, adding to the appearance of drowning at the time of autopsy examination of the lungs.

With continued cool or cold water submersion, the biochemical processes and electrical impulses of the nerves to the skin and importantly the muscles slow leading to muscle fatigue and loss of strength resulting in impaired ability to maintain head above water or to self-rescue. Therefore, the risk of drowning is heightened. [14] This encompasses the second stage.

With continued contact with cold water, deep tissue cooling (the third stage) signifies the onset of hypothermia. Immersion of bodies in cold water for prolonged periods puts one at particular risk for drowning due to the physiologic effects of hypothermia, and death can result from hypothermia alone.[14,17,18] Hypothermia causes suppression of the body's metabolism, blood flow, and brain function which translates to reduced O_2 requirements and virtually all organ systems are ultimately affected. The normal core body temperature is approximately 37°C (98.6°F). Hypothermia occurs when the core body temperature falls below 35°C (95°F). Cold water has a conductivity 25 times that of air causing the body to cool four to five times faster in water than in air. This is in addition to body heat lost through respiration, urination, and sweating.[14,17,18] Previous studies have found that prolonged immersion (upward of six hours or more) and cold water temperatures ranging from below 0°C to just below 20°C (or 32–68°F) are important risk factors for death due to hypothermia. Other studies have illuminated additional risk factors, including lower body fat, lack of clothing, exertional activity, intoxication, and the use of certain prescription medications that can accelerate the onset of hypothermia.[14,17,18]

The body experiences a number of symptoms alongside a series of physiologic changes with the development of hypothermia.[14,17,18] Initially, there is diffuse body pain followed by shivering, which is the body's attempt to generate heat and is accompanied by increased respiratory rate, heart rate, and blood pressure. With falling body temperature, pain and shivering abate and vital signs change, with a decrease in respiration, heart rate, and blood pressure. Decreased muscle strength is also noted. With continued cooling to around 33.9°C (93°F), disorientation and confusion ensue. Reduced and eventual loss of consciousness appears with core body temperatures ranging from 30°C to 32°C (86°F to 90°F). With the loss of consciousness, submersion occurs more readily with subsequent drowning. When the core body temperature reaches 30°C (86°F) or lower, death becomes more likely and even more so at a core body temperature of approximately 24–28 °C (75–82°F). The time to death after cold water immersion is dependent on the temperature of the water and the length of exposure and the colder the water the faster the time to death. For example, incapacitation and death will likely occur within 30 minutes to an hour, respectively, in water at a temperature of 6°C (43°F).[14,17,18] The rate of body cooling and the temperature at which certain signs and symptoms occur or when death occurs will be dependent on the temperature of the water and on a number of human factors including the degree of fitness, the amount of body fat, sex, and the type of clothing or protective gear worn. Full neurological recovery following cold water immersion has been reported in children, and rarely in adults, and is believed to be due to a more rapid deep body cooling of a smaller body in combination with the decreased metabolism and oxygen demand of the brain and heart.[15,36,37] Rarely, sudden cardiac death occurs upon immediate immersion into freezing water secondary to rapid changes in heart rate and blood pressure as a result of the secretion of hormones called catecholamines.[14,17,18]

Warm-Water-Related Deaths

Recreational warm and hot water immersion or bathing gives rise to subjective feelings of euphoria, relaxation, and a sense of well-being, making this an attractive social activity. Hot water immersion may be part of cultural tradition such as Ofuro tub bathing in Japan in which immersion in deep hot water (38–43 ° C or 100–109.4°F) as high as the neck for up to 15 minutes is done.[14] The water within older recreational hot tubs can reach temperatures as high as 43°C (109.4°F).[36] Prolonged immersion in very warm and hot water can be problematic in the body's ability to regulate the core temperature as normal cooling via sweating and evaporation from the skin is impaired and limited to the head and neck only leading to elevated body temperature or hyperthermia. Other effects include elevated heart rate, abnormal heart rhythms, dehydration, thickening of the blood, and fainting. and produce physiological changes that may result in hyperthermia. These effects also put a particular strain upon the cardiovascular system, which could be deleterious in those with preexisting heart disease, such as hypertensive heart disease and coronary artery disease. Individuals with diabetes and seizure disorder may also be at greater risk for complications of these conditions precipitated by prolonged warm water immersion. The physiological effects with or without preexisting medical conditions put one at risk for submersion and drowning or death due to hyperthermia. The very young and the elderly are particularly at risk for hyperthermia due to the body's lessened ability to regulate body temperature changes at those age extremes. Other activities such as competitive swimming and deep diving in warm tropical waters pose an increased risk of hyperthermia and drowning.[14]

Individuals who have consumed alcohol or taken drugs and medications that cause central nervous system and respiratory depression or have side effects of drowsiness or light-headedness are at risk of drowning and hyperthermia during prolonged warm water immersion.[38,39] These risks are magnified in individuals with preexisting medical conditions, such as heart disease and seizure disorders.

Position of Body in Water after Drowning

With drowning in large, deep, natural bodies of water, the body will assume different positions within the water column, dependent upon a multitude of factors both human and environmental.[40,41] Human factors affecting buoyancy and density include the types of clothing worn, body fat composition, presence of air or exogenous fluid in the lungs and gastrointestinal organs, whether the individual was alive or dead upon submersion, and the degree of body decomposition. Factors relative to the water include water depth, water temperature, water salinity, and entrapment by underwater debris. Characteristics of waves and currents are additional factors that relate to the degree of body displacement from the original location of the drowning. Many of these factors will be of interest to or will be encountered by water death investigators and technical recovery personnel and their recognition will aid in providing direction for search and recovery efforts. A more detailed discussion on this topic also follows in subsequent chapters.

Generally, in calmer freshwater, as the fluid displaces air in the lungs and gastrointestinal tract and with increased density, the increase in specific gravity will cause the unencumbered body to sink to the bottom, assuming a prone position with face down, buttocks up, and arms and legs dangling down. This has been referred to as the **drowner's pose**. In saltwater, the body will assume this position but may not sink to the bottom, as a result of increased buoyancy. Exposed body regions, such as the forehead, back of arms, and knees, may come in contact with and scrape against the bottom surface (being propelled by the wave and current action) causing injury in the form of abrasions and lacerations. Injury to the more accessible parts of the body, such as the face, may also result from predation by marine life. Deep currents and snags may keep the body submerged, and currents alone may move the body great distances. Bodies may also be intentionally weighted down and may be kept from resurfacing for a time, but eventually, internal gas production due to decomposition will allow the body to rise to some level remaining submerged or rise to the surface. The time to resurfacing will be dependent upon water temperature, whereby bodies in warmer waters resurface within days and those in cold and deeper waters, weeks or longer.[17] A body submerged in cold water with delay in resurfacing will also delay its visual location and recovery, (absent the use of other types of underwater location methods) until such time that decomposition with gas production is sufficient enough to bring the body to the surface.

Waterborne Illness

Although not directly related to drowning, exposure to various water sources may lead to illness and death as a result of contact with various microorganisms and chemicals. The Waterborne Disease and Outbreak Surveillance System (WBDOSS) collects data on waterborne disease and outbreaks associated with treated and untreated recreational water, drinking water, and environmental and undetermined exposures to water. WBDOSS is a national surveillance system started in 1971 as a partnership between the Centers for Disease Control and Prevention (CDC), the Council of State and Territorial Epidemiologists (CSTE), and the U.S. Environmental Protection Agency (EPA). Surveillance summary reports regarding sources of outbreaks, circumstances, and numbers of individuals involved, over specified time periods, are available from the Centers for Disease Control and Prevention website and provide important public health recommendations such as maintaining and improving pool water quality by adherence to the Model Acquatic Health Code (MAHC) (www.cdc.gov/mahc/pdf/2018-MAHC-Code-Clean-508.pdf). Recent reports cover the time periods 2000–2014 and 2011–2012. [42,43]

Surveillance of outbreaks associated with treated recreational water covering 2000–2014 time period identified 27,219 cases and 8 deaths.[42] Certain chemicals along with a variety of pathogens causing gastrointestinal and respiratory illness were identified and included Cryptosporidium, Giardia, Legionella, Pseudomonas were identified. Cryptosporidium continues to be the most common pathogen due to its resistance to even the recommended level of chlorine. Hotels were the most frequent setting associated with outbreaks. Pools, hot tubs/spas, water parks were the typical sources of the pathogen or chemical exposure.

During the 2011–2012 time period, 21 outbreaks were reported with the Escherichia coli O157:H7 pathogen, which can cause severe gastrointestinal illness, identified in a third or 7 of those cases.[43]

Recreational water activities in predominantly saltwater environments can also result in toxic exposures from pathogenic bacteria and other microorganisms and their toxins. Surfers are particularly prone to lacerations caused by contact with the surfboard. These injuries may become infected with a number of types of pathogens, including *Streptococcus* spp., *Escherichia coli*, *Pseudomonas aeruginosa*, *Mycobacterium marinarum*, *Staphylococcus aureus*, and *Vibrio* spp., which must be diagnosed and treated with the appropriate antibiotics.[44] Surfers and swimmers alike are at risk of exposure and envenomation by stinging organisms called coelenterates (jellyfish, Portuguese man-o'-war, and box jellyfish). These organisms cause painful skin lesions and potentially systemic anaphylactic reactions, which can become life-threatening. Deaths are specifically caused by a hypersensitivity reaction or the direct effects of toxins on the heart, brain, and kidneys.[45,46] The so-called sea bather's eruption results from exposure to larval coelenterates, causing an itchy skin rash and a hypersensitivity reaction.[46] Dinoflagellates are a diverse group of microalgae and the major cause of harmful algal blooms (HABs) and liberate harmful neurotoxins and hepatotoxins that cause poisoning upon consumption of contaminated shellfish or respiratory illness through water or aerosol exposure.[47]

Additional discussion regarding water-related environmental hazards appears in Chapter 2.

Importance of a Good Scene Investigation

It cannot be emphasized enough that the determination of cause and manner of death does not occur in a vacuum in which the autopsy alone provides all of the answers, especially as it pertains to water-related deaths. Certain key questions surrounding any death must be answered and correlated with the autopsy and toxicological findings within the context of all available historical data:

- Who is the decedent?
- How, where, and when was the decedent discovered?
- How did the decedent get to the location in which he or she was discovered?
- What is the cause of death and how did the death come to be?

For bodies recovered from the water, Dr. Davis stresses questions of investigative importance that should be considered:[5]

- Was the victim alive or dead before entry into the water?
- Did the victim drown?
- Why did the victim get into the water in the first place?
- Why was the victim unable to survive the water?

The body and the death scene can possess a wealth of information and evidence which must be identified, documented, and carefully preserved. This may be difficult in certain natural watery environments with moving or swift water. Identification of a decedent and proper collection with preservation of evidence are critical factors in any investigation, especially those in which the death may be suspicious for foul play. The recognition of these critical factors not only builds toward the accurate determination of cause and manner of death but also helps to eliminate questions regarding contamination and improper handling of evidence, which could potentially compromise or prolong future court proceedings.

The medicolegal death investigator (MDI) is the "first responder" of the coroner or medical examiner's office. MDIs are trained individuals and may be certified by the American Board of Medicolegal Death Investigators (ABMDI) upon successful completion of a training course and an examination. They may otherwise have previous medical, legal, mortuary, and law enforcement training and experience and serve as the coroner's or medical examiner's death investigator. As representatives of the coroner's or medical examiner's office, medicolegal death investigators serve as an initial point of contact for law enforcement and technical recovery personnel and the conduit of information between these personnel and the forensic pathologist. The MDI is instrumental in obtaining relevant death scene information through scene visitation with photographic documentation followed by completion of a report, which will be reviewed by the forensic pathologist. Generally, the investigator will document bodily findings relative to a submerged body in addition to the environmental and water conditions whether in a natural setting or indoors. Documenting the position of the body *as found* prior to their arrival becomes vitally important in determining if the victim was submerged at all and if so to what degree as in the case of bystander resuscitation in which the body has been removed from its original submerged position or otherwise repositioned. Noting the presence, condition, and state of dryness or wetness of the body and the presence or absence of clothing is important for any death scene, especially for water-related deaths. Certain scenes will require a focus on documenting or uncovering additional pertinent findings. Signs of bathing, such as the presence of nearby wet towels, the position of the bathtub drain, the proximity of electrical devices, and any evidence that the Ground Fault Circuit Interrupter (GFCI) was tripped, the height soap scum level in the bathtub, or signs that the body was moved, are some important factors for bathtub drownings. In pool drownings, the presence of a lifeguard, video surveillance, witnesses to a person in distress, unsecured access points, and victim swim ability are relevant investigative information. In drownings occurring in natural environments, underwater and land topography, weather conditions, water temperature and conditions, use of safety gear if any, signs of intoxication, state and type of dress, and signs of bodily injury are important to note. Other important information includes any medical and psychosocial history or history of remote or recent trauma that can indicate a physical disability. Deaths occurring under homicidal or unknown circumstances or in which unusual bodily findings are reported may warrant consultation with and scene visitation by the forensic pathologist.

The investigation of sudden deaths in toddlers and older children necessitates answering of similar key questions of investigative importance. Furthermore, the investigation of sudden deaths in infants, particularly ones from 1 to 12 months of age, requires a systematic and consistent approach to documentation. The **Sudden Unexplained Infant Death Investigative Reporting Form** (SUIDI-RF) is a guide for death investigators that allows for the standardized collection of demographic, social, and medical history and information regarding the terminal events preceding the infant's death. This form provides essential information to the pathologist prior to the performance of the autopsy to assist in the identification of certain environmental hazards that may pertain to the cause of death or aspects of the medical history that necessitate further investigation via laboratory testing. MDIs will utilize this form to guide their investigation. The downloadable form, including instructions on how to use it, is available on the Centers for Disease Control and Prevention website.[48]

The Role of the Coroner/Medical Examiner in Medicolegal Death Investigation

Forensic medicolegal death investigation involves the application of the scientific disciplines of forensic pathology and the forensic sciences for the resolution of medicolegal issues and in order to inform the public and the broader scientific community of the outcome of an investigation into any death. It is through completion of the death certificate, provision of an annual death statistical report, provision of expert court testimony, and community education that the lay, legal, and scientific communities become informed about deaths resulting from disease, infection, or injury. The reporting of death trends has far-reaching benefits for both local and global health through the fostering of epidemiological and medical research, allocation of health care dollars, and the creation of strategies to reduce morbidity and mortality.