Establishing the Cause and Manner of Death for Bodies Found in Water

186

Philippe Lunetta, Andrea Zaferes, and Jerome Modell

Establishing the cause of death in bodies found in water is one of the most challenging tasks in forensic medicine. Even if the cause of death is ascertained as drowning, a definite verdict concerning the manner of death, for example, by accident, suicide, or homicide, is not always achieved.

Consistent conclusions on cause and manner of death rely upon integrated assessment of autopsy findings, the individual characteristics of the victim, and circumstances surrounding death. Victim identification, evaluation of post-mortem submersion time, and localization of the site of death are essential steps of this assessment process.

In many countries, however, the responsibility for establishing the etiology of death of a body found in water rests with a medical doctor, a coroner, or another authority who lacks any forensic or medicolegal training. The cause of death as drowning is, often, established solely on the fact that the body was found in the water.

P. Lunetta (✉)
Department of Forensic Medicine, University of Helsinki,
PO Box 40, Kytösuontie 11, 00300 Helsinki, Finland
e-mail: philippe.lunetta@helsinki.fi

A. Zaferes
Lifeguard Systems,
PO Box 548, Hurley, NY 12443, USA
e-mail: az@teamlgs.com

J. Modell
Department of Anesthesiology, College of Medicine, University of Florida,
PO Box 100254, Gainesville, FL 32610, USA
e-mail: jmodell@anest.ufl.edu

J. Bierens (ed.), *Drowning*,
DOI 10.1007/978-3-642-04253-9_186,

186.1 General Approach

It should be obvious that it requires thorough police investigations and a comprehensive medicolegal and autopsy examination to be able to consider that accidental drowning has been the cause and manner of death when a corpse is found in water. For these examinations, several aspects have to be included.

186.1.1 Identification

Bodies recovered from water are sometimes, during the first phases of investigations, unidentified. Victim identification is a crucial step since personal history can furnish important clues to link circumstantial data and post-mortem findings to the actual death. During the early post-mortem period, identification may be hampered because personal documents can be damaged in water, washed out of the clothes, or because clothing and other personal effects are lost in water. Post-mortem injuries or advanced post-mortem changes can hamper visual identification or fingerprinting. Mass disasters occurring at sea (Chap. 190), as well as bodies drifting from the coast of one country to another country (Chap. 179), are additional challenges for victim identification. The common criteria for individual identification apply also to bodies retrieved from water and include visual characteristics, fingerprinting, odontological, and DNA methods.

186.1.2 Post-mortem Submersion Time

Great caution is essential in employing post-mortem changes occurring in a corpse in water to assess the post-mortem time of submersion and the reliability of the accounts of witnesses [1]. Post-mortem changes can be relatively unpredictable and can significantly vary even during a short time interval such as that elapsing from the recovery of the body to the start of the external examination or autopsy.

- In warm water, skin maceration on fingertips appears within minutes after exposure and on the palm after some hours. Prolonged exposure to water causes skin to slip off from the hands in a glove fashion. In cold water, this occurs in several weeks or months, but at warmer temperature, it may take only some days.
- Cooling of a body in water is faster than on land since the thermal conductivity of water is more than 20 times higher than that of air. A naked corpse in cold water cools approximately twice faster than a body on land.
- Hypostasis and rigor mortis are influenced by environmental and individual factors similar to those acting on land, with some unique variables. Hypostasis can appear, due to movements of the corpse in water, in any pattern around the body or, conversely, be consistent with the head- and leg-down positions the body often assumes in water. The muscular activity during the drowning process may lead to earlier onset and stronger development of rigor. On the other hand, water movement can prevent its observable development.

- At water temperatures of 4–5 °C, no post-mortem chromatic skin changes may be evident even after weeks, while at 15–20 °C, these can appear after a few days. In warmer climates, advanced decomposition with gas production can occur in less than 1–2 weeks.

The late decomposition of a body in water occurs generally slower than in air. However, once the body floats or is ashore, decomposition develops rapidly. Factors influencing the decomposition include water temperature, bacterial content, and injuries, which create portals of entry for insects and bacteria. Various scavenger organisms, which feed on the decomposing bodies, produce artifacts and quicken the course of the skeletonization. The movements of the corpse in water can cause, at this stage, distal and then proximal joint disarticulation.

186.1.3 Site of Death

Detection of the site of death can be crucial in establishing a link between the actual drowning and a given individual. A body can be found in water at or near the site of drowning, or more distant, at times hundreds of kilometers away (Chap. 179). In unwitnessed cases, police and other law investigators play a key role to determine the site of drowning. These investigations can be assisted by use of specific technologies or expertise, such as computer systems (Chap. 184) or taxonomical comparison between diatoms found at the site of recovery and in the organs of the victim (Chap. 186.3.4).

186.1.4 Circumstances

The gathering of circumstantial data requires the coordinated action of police investigators and medical examiners. In aquatic environments, the scene to be investigated can be much wider and volatile than it is on land, and it can extend to an underwater setting (Chap. 185). For these reasons, specific training should focus on the crucial role of law enforcement personnel and first responders in observing, documenting, and eventually securing evidence from the initial scene of any drowning incident [2].

186.2 Scene Investigations

The present chapter is a forum too limited in nature to consider the range of multiple challenges arising during scene investigations related to bodies found in water. Moreover, it is difficult to give targeted recommendations to the multiple parties which may be involved in these scene investigations. The competent authority, the parties involved, their respective roles, and the legal context in which they operate can significantly vary among countries worldwide.

In general, the scene should always be *a priori* considered suspicious, no matter how benign the initial presentation. This is particularly true when the reporting person or persons are the only individual to have seen the victim in the water. Simply attempting to fit circumstances and a solo witness report to an accidental drowning creates tunnel vision which can lead to biased investigations. Each party involved in the investigation, *imprimis* law enforcement and a medicolegal examiner, should not rely exclusively on each other to suggest any suspicious findings in order to continue or perform a more specific investigation.

First responders must document, and immediately report to the competent authority, inconsistencies between reports of witnesses, alleged submersion time, post-mortem changes and external injuries. Similarly, suspicious positions or any inconsistency between position of the body and hypostasis should be documented before the corpse is removed or moved from its original position. For example: a child in a bathtub under a running faucet. In nonfatal cases, hospital personnel must similarly report and document any suspicious injury and possibly the account of the drowning event. First responders should also provide reports on the circumstances and the victim's initial condition, the changes made to the scene, such as victim position, resuscitation attempts, and post-mortem injuries that occurred during the retrieval procedures.

Law enforcement officers must perform state-of-art scene investigations. They should not overlook specific elements such as mapping and documentation of wet and dry surfaces. They must search for wet clothing or towels and water-soaked diapers in the garbage, as well as obtain on-site documentation and collect data on volatile post-mortem changes. Critical analysis of any emergency service call may yield additional clues, such as general sense, background sounds, and consistency of cardiopulmonary resuscitation (CPR) while on the phone.

An assessment of the physical and emotional condition of the reporting person or persons should be made insofar as possible. In specific cases, a complete and timely forensic and medicolegal examination of the reporting person can be useful to collect trace evidence, to describe the injuries, and to reveal alcohol and drug intoxication.

Thorough scene investigation and incident reconstruction may benefit from a multidisciplinary approach (Chap. 187). Various experts can be involved on a case-by-case basis, such as experts in vehicle-incident reconstruction in cases of bodies found in submerged cars.

186.3 The Autopsy Diagnosis of Drowning

Morphological, biochemical, and chemical changes have been extensively investigated in the search for reliable criteria for the post-mortem diagnosis of drowning [3, 4]. At present, broad agreement exists as to the nonspecificity of morphological changes, while most, if not all, laboratory methods for drowning are considered of limited practical utility. A certain consensus exists on the potential of the diatom method, but its reliability remains debated [1, 3].

186.3.1 Macroscopical Changes

The main macroscopical changes associated with drowning are external foam visible at mouth and nostrils, frothy liquid in airways and lung overexpansion. The changes are related to the penetration of drowning liquid into the airways. In a survey of 1,590 bodies found in water, these changes were found in 17.3, 46.5, and 42.1 % of the cases, respectively. These changes fade with the onset of putrification. Moreover, no one of these changes is specific for drowning [5].

The external foam is one of the most valuable diagnostic findings. However, it can be washed out while the body is in water. The frothy liquid in the airways may occur also in deaths other than drowning, for example in drug intoxication. The lungs of drowning victims are often overdistended. They occupy most of the pleural cavity and may display overlapping of the anterior margins. In overdistended lungs, the pulmonary liquid content can be pronounced. This is known as *emphysema aquosum*. This is however not always the case.

The volume of liquid that penetrates into the airways during the drowning process is a central issue of medical research on drowning. The hypothesis that death can occur without liquid aspiration has been linked to the observation at autopsy of drowned people of apparent dry lungs. Recent studies, however, have suggested that actual dry lungs do not occur in persons who drown [6].

Lung weight is a misleading criterion for drawing a distinction between wet and dry drowning. Low weight and apparent dry lungs can be associated with signs of liquid penetration. In a series of 578 adult drowning victims with no putrefaction changes, 120 subjects had a total lung weight less than 1,000 g. External foam was found in 35 %, frothy liquid in 72.5 % and overdistension in 70 % of the cases [6].

186.3.2 Microscopical Changes

The main light microscopy signs which are associated with drowning are foci of acute lung emphysema with overdilatation of alveoli, thinning and lacerations of septa, capillary congestion, intra-alveolar edema, and hemorrhages. At times, exogenous particles in the airways may be detected. Factors such as the depth at which the body is submerged, the duration of the drowning process, and the onset of post-mortem artifacts limit the diagnostic utility of these lung changes, even if studied by computer-assisted morphometry or electron microscopy [1].

186.3.3 Laboratory Methods

Physical, chemical, and biochemical blood changes that may occur in drowning victims have been investigated for over 100 years [1, 3]. These studies have focused on blood composition, such as electrolytes, and exogenous substances present in the drowning media, such as plankton, bacteria, and pollutants, which may enter the

bloodstream during the drowning process. Strontium [Sr^{++}] remains the most studied exogenous ionic tracer for drowning, due to its high seawater-serum concentration ratio [7]. The concentration of strontium however differs widely among geographical areas. For instance, the concentration in water is higher in the Mediterranean than in the Baltic Sea. While many studies have disputed the values of these methods, others have reiterated their potential. At present, laboratory methods are considered of limited practical utility due to post-mortem changes occurring in the body and the effects of protracted submersion [3].

186.3.4 The Diatom Method

Diatoms are unicellulate planctonic organisms. The diatom test is based on the fact that diatoms are carried to the lungs by the drowning liquid, penetrate into the bloodstream and disseminate to closed organs [8]. Routine diatom analysis includes sampling of lung, brain, kidney, liver, and bone marrow tissue under sterile conditions, tissue processing, and analysis of the specimens by light microscopy. Diatom dimension ranges from 2 μm to over 500 μm, but diatoms penetrating into the bloodstream have generally a size less than 60 μm. Taxonomic comparison of diatoms in the putative drowning media and in the organs of the victim assists in the diagnosis of drowning and in differentiating between fresh- and saltwater drowning [9].

The main criticism of the diatom method is finding diatoms in non-drowned cases. Due to the ubiquity of diatoms in water, air, and land, false-positives can be related to antemortem penetration of diatoms into the organism via gastroenteric absorption, post-mortem penetration during submersion, or contamination during sample collection and preparation. However, latest quantitative studies on diatoms in non-drowned bodies, obtained by strict protocols to avoid contamination, have revealed an exceedingly low number of contaminating diatoms of less than 1–2 diatoms per body. These values are clearly below the cutoff values recommended for the diagnosis of drowning [9–11]. A low diatom concentration in the drowning media associated with low volume of liquid aspirated may yield negative diatom results in drowning victims. However, the possibility of false-negative cases relies also on the volume of tissue sampled at autopsy.

186.3.5 Emerging Diagnostic Methods

Various studies have been recently performed to investigate new methods and markers for diagnosis of drowning: from pulmonary surfactant changes and activation of lung aquaporins to extraction of bacterial and planktonic DNA and RNA from internal organs [12–15]. Further investigations are needed to validate these studies and assess their actual potential. Imaging technologies such as computed tomography (CT) and nuclear magnetic resonance (NMR) are increasingly used. Their utility is evident in fatalities related to self-contained breathing apparatus (SCUBA) and is being evaluated in other drowning cases as well [16, 17].

186.4 Contributing Factors Detected at Autopsy

Post-mortem toxicology should always be performed to ascertain the association between alcohol and drowning. However, the percentage of drowning cases autopsied and tested for alcohol and other drugs varies widely, even within high-income countries. Most studies, from high-income countries, report 25–50 % of alcohol-positive drowning. In Finland, where a medicolegal autopsy is performed in 100 % of drowning cases and forensic toxicology in more than 90 %, over 70 % of unintentional drowning victims, 15- to 64-year-olds, have a blood alcohol concentration (BAC) ≥0.5 g/L. A recent survey conducted on 2,828 consecutive drownings revealed that the proportion of alcohol-positive suicidal and homicidal drowning was 32.7 and 63.6 %, respectively. One or more psychotropic drugs were detected in 25.7 % of unintentional drowning, in 64 % of suicidal drowning, and in 36.4 % of homicidal drowning [18].

As to medical conditions, chronic – mostly cardiovascular – diseases are a common collateral finding in the adult and elderly drowning population. When no acute changes are detected at autopsy, it is very challenging to assess the actual role of chronic diseases in the events leading to drowning. The same difficulties may arise in unwitnessed drowning in subjects with epilepsy.

Bodies found in water may reveal injuries sustained before submersion, during the fall into the water, or as a consequence of the impact with the water surface or with the bottom. Victims can also sustain injuries while in the water, by being dashed by waves against a steep shore, by drifting along the bottom, or by being struck by a boat. Boat propellers produce incision wounds on the body, amputation or even dismemberment. These injuries can trigger the drowning episode or can contribute to drowning by rendering the victim unconscious or unable to swim.

Sometimes, injuries are promptly detectable at victim's external examination. In other cases, injuries, even crucial, are detected only during autopsy. Head and neck injuries can occur due to the impact with the bottom of shallow water. Bone fractures and organ lacerations can occur due to impact with the water surface, following a fall from a bridge. Injuries detected at victim's internal examination may also be crucial in revealing violence inflicted in a criminal context.

Vital injuries may be difficult to differentiate from post-mortem injuries since bleeding can be washed away after death, and later, advanced decomposition can mask crucial injuries such as ligature marks, cutting, or gunshot wounds. Hence, post-mortem artifacts, which occur during retrieval procedures, should always be recorded and reported to investigators and medical examiners.

186.5 Causes of Death in Water Other than Drowning

Virtually all natural or injury deaths may occur while in water. With the exception of epilepsy, limited data exist on natural and injury deaths in water. The occurrence of sudden deaths in cold water due to vago-vagal inhibition producing cardiac arrest has been hypothesized to explain immersion deaths with no obvious findings at autopsy.

Molecular autopsy represents an emerging tool to investigate negative autopsy deaths. Genetically determined cardiac arrhythmias, especially the long QT syndrome (LQTS), may explain deaths in water occurring without apparent cause in good swimmers. Yet, during the last decade, only few life-threatening arrhythmia-related fatal drowning have been reported [19, 20]. Molecular autopsies have, however, crucial implications. In obscure cases, a single mutation can influence the judicial outcome by raising a reasonable doubt as to the actual cause and manner of death.

In SCUBA accidents, the most common cause of death is drowning. However, diving fatalities are frequently related to gas-pressure changes, which may cause pulmonary barotrauma, decompression sickness, N_2 narcosis and O_2 or CO_2 intoxication.

186.6 Accident, Suicide, or Homicide?

186.6.1 Unintentional

The vast majority of drownings are unintentional. The wide range of settings and circumstances in which accidental drowning generally occurs, together with the main individual risk factors, have been addressed in several epidemiology studies. Reliable witnessing and exclusion of other manners of death are generally the strongest factors on which the diagnosis of accidental drowning can be drawn, but are not always the case.

186.6.2 Suicide

In most countries, suicidal drowning is less common than is unintentional drowning (Chap. 20). In suicide by jumping from high bridges, drowning is only one of the possible causes of death, since death may also be due to trauma sustained before, during, or after impact with the water surface.

Suicide notes, witnessing and injuries related to the combination of drowning with other suicide methods, such as stubbing or gunshot, are among the more significant factors which may lead to a diagnosis of suicide by drowning. Tentative cuts or wounds performed by the victims before the actual suicide, for instance on the wrist or neck, are also found in suicidal drowning. Factors such as previous suicide attempts, suicide ideation, and psychiatric history must be considered judiciously, since they can occur also in victims of homicide and unintentional drowning [21].

To ensure the success of the suicide, some suicide victims weight themselves before entering the water by filling a bag or their pockets with heavy objects or stones. Other suicide victims bind their hands or feet with rope. When retrieving a weighted body from water, the differential diagnosis with homicide by drowning, body disposal in water, or even sexual rituals involving bondage in water must be appropriately considered. Ascertaining the origin of the weight and whether the victim could have applied the weight or the ropes alone are important steps in this differential diagnosis.

186.6.3 Homicide

Homicidal drowning is generally perpetrated by a physically stronger assailant against a weaker victim, generally a child or an incapacitated adult, often in a bathtub or in shallow water. Homicide by drowning can also be the result of pushing someone off a boat unobserved, throwing a person into a body of water, during play or as a joke and then failing to rescue. In these cases, the scene investigation will reveal no indication of a fight or foul play. The victim will show no specific injuries, and it will be difficult to convict the perpetrator in courtroom. In some instances, a late suspicion of homicide arises in connection with police investigation or life-insurance issues, after drowning has been first classified as an accident or suicide.

Homicidal drowning victims are often incapacitated by disease, alcohol or drug intoxication. In positive toxicology cases, investigations should establish whether the victim consumed voluntarily drugs or whether the perpetrator has had an active role in drug ingestion. Homicide premeditated by drowning lacks often clear signs of injuries, whereas in other cases, drowning can be the final stage of an assault involving additional forms of violence, such as strangulation, stabbing or beating. Although unusual, the possibility of a homicide during sex-related breath-holding rituals and sadistic actions should be considered.

Drowning as a form of fatal child abuse, especially in the bath, can be difficult to distinguish from unintentional drowning, Sudden Infant Death Syndrome (SIDS), or other natural death. There is often little or no evidence of foul play at drowning sites or on victims, since the pressure required to keep a child underwater often leaves no detectable sign of violence. The diagnosis is thus generally based on characteristic features of child abuse, including previous history of abuse, lack of resuscitation attempts, delay in seeking care, inconsistency of explanations and former injuries detected at autopsy.

Drowning may occur also at the time of birth. Delivery may occur in adverse conditions in a bathtub or other water environments. In these cases, it is crucial to determine whether the fetus was already dead at the time of delivery or whether the victim was breathing after delivery, and in the latter case whether drowning occurred accidentally or was purposely inflicted.

186.6.4 Undetermined

Since the introduction of the eight's revision of the International Classification of Diseases (ICD) in 1967, drowning can be classified under the category *undetermined*, when it is unclear whether it has been unintentional or purposely inflicted. Inherent difficulties related to circumstances of drowning or individual factors may hamper the determination of the manner of death in drowning [21]. Various reports exemplify these difficulties: bathtub drowning compatible with homicide or suicide but likely associated with epileptic seizures; a drowned young male boating with an inflatable boat on a lake, found dressed in a knight's armorlike chain-mail coat and

trousers, consistent with both suicide and accident during fantasy play; and a diver found drowning in an underwater cave with a knife wound in the thorax consistent with both homicide or suicide committed while running out of air to avoid the agony of drowning [1].

186.6.5 Disposal of Bodies

Disposal of corpses in a water setting, after a homicide perpetrated on land, may reflect three aims:

- Concealing the body with the expectation that it will remain underwater or will be transported far away from the scene of the crime
- Preventing or retarding the identification of the victim and of inflicted injuries, due to post-mortem changes
- Simulation of natural, accidental, or suicidal death in water

The disposal of a victim in water after a homicide perpetrated on land near a body of water does not require complex action and does not necessarily imply premeditation. Conversely, when the murder is perpetrated far away from the site of concealment, disposal requires elaborate actions such as that the body is being weighted, hidden in a sack or other container, or even dismembered. Homicidal drowning followed by disposal of the victim on land must be also appropriately considered in any suspected death. Disposal in cribs or bed to stage a sudden unexpected infant or child death is not infrequent in pediatric homicidal drowning.

References

1. Lunetta P (2005) Bodies found in water: epidemiological and medico-legal issues. Doctoral Dissertation, Helsinki University, Helsinki
2. Zaferes A, Hendrick W (2007) Homicidal Drowning – what first responders can do? FireRescue 1, Sept 12
3. Lunetta P, Modell JH (2005) Macroscopical, microscopical, and laboratory findings in drowning victims – a comprehensive review. In: Tsokos M (ed) Forensic pathology reviews, vol 3. Humana Press, Totowa, pp 1–69
4. Piette MH, De Letter EA (2006) Drowning: still a difficult autopsy diagnosis. Forensic Sci Int 163:1–9
5. Lunetta P, Penttilä A, Sajantila A (2002) Circumstances and macropathologic findings in 1590 consecutive cases of bodies found in water. Am J Forensic Med Pathol 23:371–376
6. Lunetta P, Modell JH, Sajantila A (2004) What is the incidence and significance of "dry-lungs" in bodies found in water? Am J Forensic Med Pathol 25:291–301
7. Pérez-Cárceles MD, del Pozo S, Sibón A et al (2012) Serum biochemical markers in drowning: diagnostic efficacy of Strontium and other trace elements. Forensic Sci Int 214:159–166
8. Lunetta P, Penttilä A, Hällfors G (1998) Scanning and transmission electron microscopical evidence of the capacity of diatoms to penetrate the alveolo-capillary barrier in drowning. Int J Legal Med 111:229–237
9. Hürlimann J, Feer P, Elber F et al (2000) Diatom detection in the diagnosis of death by drowning. Int J Legal Med 114:6–14
10. Bortolotti F, Del Balzo G, Calza R et al (2011) Testing the specificity of the diatom test: search for false-positives. Med Sci Law 51:S7–S10

11. Lunetta P, Artto Miettinen A, Spilling C et al. (2013) False-positive diatom test: a real challenge? A post-mortem study using standardized protocols. Legal Medicine (Tokio) 5:229–234
12. Stemberga V, Stifter S, Cuculić D et al (2009) Immunohistochemical surfactant protein-A expression: fatal drowning vs. postmortem immersion. Med Hypotheses 72:413–415
13. Hayashi T, Ishida Y, Mizunuma S et al (2009) Differential diagnosis between freshwater drowning and saltwater drowning based on intrapulmonary aquaporin-5 expression. Int J Legal Med 123:7–13
14. Kakizaki E, Ogura Y, Kozawa S et al (2012) Detection of diverse aquatic microbes in blood and organs of drowning victims: first metagenomic approach using high-throughput 454-pyrosequencing. Forensic Sci Int 220:135–146
15. He F, Huang D, Liu L et al (2008) A novel PCR-DGGE-based method for identifying plankton 16S rDNA for the diagnosis of drowning. Forensic Sci Int 176:152–156
16. Levy AD, Harcke HT, Getz JM et al (2007) Virtual autopsy: two- and three-dimensional multidetector CT findings in drowning with autopsy comparison. Radiology 243:862–868
17. Christe A, Aghayev E, Jackowski C et al (2008) Drowning–post-mortem imaging findings by computed tomography. Eur Radiol 18:283–290
18. Lunetta P, Smith GS, Lillsunde P et al (2011) Drowning under the influence of drugs and alcohol. In: Scarr J et al (eds) World Conference on Drowning Prevention, Danang, Vietnam, 2011. International Life Saving Federation, Leuven, pp 97
19. Lunetta P, Levo A, Laitinen PJ et al (2003) Molecular screening of selected long QT syndrome (LQTS) mutations in 165 consecutive bodies found in water. Int J Legal Med 117:115–117
20. Tester DJ, Medeiros-Domingo A, Will ML et al (2011) Unexplained drownings and the cardiac channelopathies: a molecular autopsy series. Mayo Clin Proc 86:941–947
21. Lunetta P, Smith GS, Penttilä A et al (2003) Undetermined drowning. Med Sci Law 43:207–214