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Drowning and Immersion Physiology

“Again, it is the circumstances which will be more helpful in distinguishing the manner of death. The diagnosis of drowning may be very difficult, especially if there is more than a few hours’ delay in retrieving the body from the water.” Knight (19__) p. 78.

“Where a considerable period has elapsed between death and retrieval of the body, the positive signs of drowning progressively fade.” p. 399 Unnamed from our sheriff’s dept

Positive physiological findings for homicidal drowning may be even more difficult to obtain. “What makes a case an accident, a suicide, or a homicide is not so much the anatomic findings, the geographic local, or the toxicology. Rather it is the scene investigation that certifies the manner of death correctly.” Copeland (1985) p. 251

Investigating officers need a strong foundation of knowledge about drowning and immersion to be able to ascertain the veracity of witness statements, drowning scenes, and the appearance of accidental death. This knowledge might highlight a subtle clue that perhaps there is more to a drowning incident than initially meets the eye.

Drowning Statistics

Annually, approximately 1500 drowning fatalities are associated with boating accidents and approximately 500 people drown a year trapped in submerged motor vehicles (Spyker 1985). The majority of drownings occur in freshwater such as swimming pools, canals, lakes, rivers, ponds, and streams. Approximately 80 per cent of drownings happen in bodies of water that are not designated for swimming (Press, Walker & Crawford, 1968; Dietz & Baker, 1974). Toddlers tend to drown in residential pools, tubs and buckets (Pearn & Hsia, 1980; Pearn & Nixon, 1977; Rowe, Arango, & Allington, (1977).

Alcohol is the single most common factor in adult drownings, and is involved in 75 per cent of adult male drownings between the ages of 20 and 35. In the United States males are five times more likely to drown than females, and blacks are approximately twice as likely to drown than white (Dietz & Baker, 1974).

When a body is found on land.

If a body is found on land, is death by drowning ruled out?

No, the victim could have been drowned, and later removed from the water. If the body of the victim was removed quickly after immersion, there may be no obvious external signs of immersion such as maceated, white, wrinkled skin. If the victim was drowned and removed from the water before cardiac arrest, which could take as much as six minutes, there may be no obvious signs of drowning discovered during the autopsy. The still beating heart maintains circulation, which can remove fluids from the lungs. Eventually the heart stops, the victim dies, and cause of death could be made to look like a non-water related accident or perhaps a natural cause.

“The positive signs of drowning, as opposed to immersion, are scanty and not absolutely specific.” p. 399 From our sheriff’s dept.

¹“Drowning does not require immersion in water... One can drown in a bucket of water, or even less.”

Perhaps only the victim’s head or face was held in the water, with the victim’s body kept dry. As discussed earlier, dunking is a historical form of punishment, interrogation, and torture. Dunking is sometimes used as a form of torture in contemporary human rights abuse incidents. “Suffocation and partial drowning are also employed, the usual intention being to suffocate partially, rather than kill. Immersion in water and foul sewage is termed ‘wet submarino’ and may lead to pneumonia” Knight (19__).

Although dunking usually has the intention of partially suffocating, not killing, the victim, sometimes death inadvertently does occur. Think of teenage boys holding the head of one of their peer group in a toilet as a prank, fraternity rite, or assault. Or consider a parent holding a child’s head in a filled tub or sink as a form of punishment or to stop, “drown-out,” the noise of a child’s crying. Perhaps sometimes not only the crying is drowned-out, but so is the child.

Complete and partial suffocation by holding a pillow over a child’s face has been well documented as a method of child abuse and murder. As child drownings are more frequently investigated for signs of foul play, we may find that ‘wet submarino’ performed by parents on their children is a more common phenomenon than is currently understood.

Pneumonia or other respiratory problems are not uncommon results of near drowning events. Perhaps a history of pneumonia could provide a clue for a history of water-related child abuse of a drowned child. Perhaps a history of a child’s intense fear of water could provide information about past water-related abuses, and possible cause of death.

The key thing to remember here, is that an apparent land-based accidental death does not rule out drowning as the cause of death. Be prepared to look for clues of drowning, consider possible autopsy findings of drowning, and perform a thorough investigation.

Five percent of near drowning victims experience secondary drowning. Near drowning means a person drowned and was saved either by quick removal from the water or resuscitation efforts. Secondary drowning occurs because of fluids and damage in the lungs that occur as a result of the initial near drowning process. Secondary drowning can happen 24 hours after the near drowning incident. This is another example of how a body can be found on land, and the original cause of death is drowning. Consider perhaps one parent saving a child from the dunking or intentional drowning by the other parent.

When the body is found in the water

When the body is found in the water does that always indicate accidental death by drowning? No, there are several other possibilities:

1. The victim was murdered on land and the victim’s body was disposed of in the water.
2. The victim was murdered by intentional involuntary submersion resulting in drowning.
3. A physical fight in or out of the water resulted in the victim dying from a combination of trauma and drowning.
4. The victim drowned because of neglect or negligence.

Table __ provides examples of each of these types of non-accidental drowning incidents.

¹ The Internet Pathology Laboratory for Medical Education, Version 2.0

A knowledge of the drowning process will aid the first responding officer to the scene of a body recovered from the water, to discover possible clues that foul play may have been involved. This knowledge can also be very helpful to the investigating officer assigned to the incident. And as non-law enforcement dive teams may be the one's to recover the body, and even be in charge of the initial scene, this information will be helpful for them to understand as well.

For example, as we will learn, lividity and position of rigor mortis might provide helpful clues of whether or not the victim was dead before entering the water. This evidence could be destroyed by the diver performing the underwater rescue or recovery. Public safety divers should be educated enough to know what physiological signs to be observant of, and they should be taught how to record this information for arriving law enforcement personnel. Dive teams should know how to record the position of the body underwater, even if the water is black. If the incident is designated as a recovery, rather than a rescue, the body should be properly bagged to maintain as much evidence as possible. The ability to properly take photographs, once the body has reached shore, is also important.

The drowning process

There are several physiological ways submersion victims can die, such as cerebral hypoxia, carbon dioxide narcosis, laryngospasm, reflex lung changes, and vagal cardiac inhibition. For most of us, these terms mean very little or even nothing. Let us examine these drowning processes in a more useful manner. To do that we must begin with a short review of respiration and pulmonary physiology. This review is also helpful for investigating officers who will read the autopsy report, which often includes such medical terminology.

Respiration and Pulmonary Physiology Review

Respiration

Oxygen is essential to life. It combines with the fuels we eat to form energy, water, and carbon dioxide. Carbon dioxide is a waste product that needs to be removed from the body's tissues. Blood carries carbon dioxide from the tissues to the lungs where it is removed from our body when we exhale. A high concentration of carbon dioxide (**hypercapnia**) combined with a low concentration of oxygen (**hypoxia**) in the blood, is what triggers us to breathe. These two triggers are sometimes called the **carbon dioxide and hypoxia drives**.

Respiration is really the process of bringing oxygen to the cells, the use of oxygen by the cells, the resulting production of carbon dioxide, and the removal of carbon dioxide from the body.

Oxygen is supplied to our cells by the air we inhale through our nose or mouth. The air passes through the pharynx, the larynx, down into the trachea, the left and right bronchi, the branching bronchioles, and into the millions of microscopic air sacs called **alveoli**. These air sacs are kept open by a fluid called **surfactant** that coats the inside of alveoli walls. If this surfactant is destroyed, by water or other fluids entering the lungs, the alveoli can collapse.

De-oxygenated, carbon dioxide-filled blood from the body's tissues is brought to the **pulmonary capillaries**, which are tiny blood vessels covering the alveoli. Oxygen from the alveoli enters the pulmonary capillaries and the blood, while carbon dioxide escapes from the blood into the alveoli. The oxygenated and cleaned blood then continues forward to nourish and clean the tissues.

Breathing

When the carbon dioxide and hypoxia drives trigger us to breathe, our trachea opens, our diaphragm drops, and our chest muscles expand. When the diaphragm drops and the chest muscles expand the lungs are stretched open to make a larger volume, creating a negative pressure inside the lungs. This negative pressure, pulls air in from the higher pressure area outside our body through our mouth or nose into the trachea and lungs to equalize the pressure inside our lungs and outside our body. Exhalation occurs when

the diaphragm raises and the chest muscles contract. When this happens the pressure inside the lungs is greater than the pressure outside our body, and if the trachea is open, air is forced out of the lungs.

Our nose and mouth lead not only to our trachea but also to our esophagus, which brings food and fluids to our stomach. Only one of these two tubes can be open at the same time, otherwise food would get into our lungs when we were eating, and air would enter our stomach when we were inhaling. When we are eating or drinking, the larynx is sealed by a flap called the **epiglottis**. Remember when your parents told you not to eat and talk at the same time? They told you that to prevent you from choking when food or fluid accidentally entered your trachea when it didn't have time to close, because you were trying to talk and swallow simultaneously.

When food or fluid touches the larynx or trachea the epiglottis reflexively attempts to close to protect the airway. This sudden closure, or larynx spasm, is called a **laryngospasm**, which can last for up to two minutes. If you ever had food or fluid “go down the wrong way” with the result that you could not inhale or exhale for a little while, you probably were experiencing a laryngospasm. This same process can occur when a person inhales with their airways underwater.

How people drown

“Officer, it was terrible, my girlfriend fell in the canal and began screaming for help. I tried to throw her something, but nothing could reach. She was screaming, for help. She began going up and down, screaming, up and down, screaming. Then she didn't come up no more. It was terrible.”

“My older son was playing with the baby in the stroller around the pool. I was laying there reading. I told him to stop running but he didn't listen, he's only three. Suddenly I heard a splash and the baby and stroller were in the deep end of the pool. I can't swim so I couldn't go in. It wasn't his fault, he was only playing. He really didn't mean it. The baby was struggling; I didn't know what to do! The boy was crying, I was yelling at him, there was nothing I could reach the baby with. Soon the baby stopped struggling and sank to the bottom. It took less than two minutes. There was nothing I could do. I couldn't think. There was so much crying. I don't swim. I ran and called 911.”

Do these statements sound plausible? Are they possible? yes, but are they likely?, no. An understanding of the different ways people can drown will be very useful when interviewing witnesses and reviewing their statements.

Adults take an average of 60 seconds to drown, and children take an average of 20 seconds. The majority of drownings are witnessed, and happen within 150 feet from the witnesses. If that is true, why do these witnesses not try to save the victim before it is too late? One of the reasons is that most people do not know what actual drowning looks like, rather they have a false perception given to them by television and movie scenes. Try this, ask a few dozen people what it looks like when someone is drowning; ask them how would they know a person was drowning? The number one answer you will get is that the drowning person is, “struggling, screaming for help, waving their arms around.” As long as a person is screaming and waving their arms around out of the water, that person is not drowning – eventually they might begin drowning, but they are not drowning yet.

Drowning is a silent event. A drowning person no longer has the ability to scream, raise her head or arms out of the water, or struggle violently. A victim might enter the water and within seconds descend to the bottom without re-surfacing as in a ‘dry drowning’ event, or they will bob for up to an average of a minute depending on the victim's age in ‘wet drowning’ event.

An interesting and possibly useful piece of drowning information is that consciousness is always lost within three minutes of involuntary submersion (Pearn 1985). It could, therefore, take up to three minutes of holding a victim underwater, for the victim to stop struggling and lose consciousness. But, interestingly, this is unlikely to be true for infants and possibly toddlers. Pearn (1985) also tells us, “One is struck by the failure of an infant to struggle as the head goes below the surface – usually the child simply holds his

breath; makes automatic, but ineffective, paddling type movements; and calmly sinks to the bottom.” This makes it much easier to consciously or ‘unconsciously’ drown infants and toddlers. If you have seen it, think of the scene in the movie *The Joy Luck Club* where an abused and very unhappy young mother simply lets her infant slide out of her hands in the washing basin; she shows no movement or emotion as the infant quietly slides to the bottom of the basin and drowns.

Often, when a drowning victim is recovered of any age, a white or pink foam will be seen in, and possibly coming out of, a drowning victim’s airways. Also, the autopsy report will generally report pulmonary edema and congestion (see table ____, column __). Sometimes the autopsy will report that the lungs are relatively dry and that there are few conclusive positive findings for drowning. Let us take a closer look at drowning and examine what is sometimes called the “march of events” of the respiratory system during drowning processes.

Dry Drowning - 10-20% of all drownings

Dry drowning victims, like wet drowning victims, die of fatal cerebral hypoxia caused by “inadequate ventilation,” namely, suffocation (**asphyxiation**). But unlike wet drowning victims who suffocate because their airway is blocked by the water or fluid they drowned in, the dry drowning victim’s airway is blocked by a laryngospasm or lung reflexes, or by physical obstructions of the bronchi such as mucus, froth/foam, or vomit.

1. The person enters the water and is hit in the face with the water or the water is cold enough to cause a shock to the body.
2. The person reflexively gasps.
3. A small amount of water is inhaled, aspirated, into the larynx or trachea causing a sudden laryngospasm, which seals off the airway.
4. The aspirated fluid irritates the bronchi linings, which begin an immediate secretion of protective, thick mucus.
5. The carbon dioxide and hypoxia drives kick in triggering the person to inhale. The diaphragm drops and the chest muscles expanded, increasing lung volume and decreasing the pressure inside the lungs. The only problem is that the trachea is sealed shut so air can not be pulled in from the outside to equalize the pressure. This negative pressure needs to be relieved, so it pulls blood fluids from the pulmonary capillaries into the alveoli. This destroys surfactant and damages alveoli.
6. The aspirated water mixes with the mucus to produce a white foam or froth. If enough blood enters the lungs the blood enters the mixture making the foam pink in color.
7. Sometimes foam and a mucus plug develop, which serves as another physical obstruction in the airway.
8. The laryngospasm relaxes shortly before death. But the physical barriers of the foam and mucus plug, along with a possible bronchiolar spasm, continue to prevent water from entering the lungs. Thus the drowning is dry.

Wet Drowning – 80-90% of all drownings

1. The person somehow ends up in the water, and for whatever reason, cannot swim to safety.
2. As the person weakens, he can no longer hold his head high out of the water. An adult’s head can weigh 12 pounds, and thus requires much energy to hold it out of water too deep to stand in. The victim sinks and reflexively holds his breath (**apnea**).
3. When the carbon dioxide and hypoxia drives trigger the need to breathe, the victim bobs up bringing only his face out of the water for just enough time to take a breath. The victim does not have the ability to hold his face out of the water long enough to take a breath and scream. The event is silent.
4. The victim begins sinking again, reflexively holding his breath, and the bobbing process is repeated several times. Soon only the victim’s mouth and nose are the only things to surface.
5. Eventually the person can no longer bob to the surface and he sinks to the bottom.

6. At some point, the carbon dioxide and hypoxia drive trigger the body to breathe. The victim begins reflexively swallowing, sometimes large quantities, of water into the stomach. Vomiting can occur, with vomitus later being aspirated when the next gasp occurs (Laughlin & Eigen, 1982).
7. Finally the drives cause a breath-holding breaking point and the victim reflexively gasps and aspirates water into the lungs.
8. Within seconds of the gasp, there is a second phase of apnea, breath-holding (Giammona & Modell, 1967).
9. When this breath-hold breaks, there is a period of involuntary gasping underwater, sometimes referred to as agonal gasping, which can last up to a several minutes.
10. Respiratory arrest occurs when the gasping ceases.
11. Cardiac arrhythmias (any change in the normal pattern of the heartbeat) and cardiac arrest follow.
12. Brain death is the last step in the process.

If large volumes of water enter the lungs, blood is sent to those areas of the lungs that are not ventilated with air. More alveoli are collapsed and damaged, more blood may enter the lungs, and the foam seen in and out of the airways can have a pink or blood red appearance.

Respiratory problems related to drowning

As stated earlier, autopsy reports on drowning victims often report pulmonary edema and congestion. **Pulmonary edema** simply means fluid in the lungs, fluid in the alveoli.

As we learned from the above descriptions of drowning processes, pulmonary edema can occur in a few ways. Let us review them and add a few new methods.

1. The person inhales (**aspirates**) fluids, which travel down the airways to the alveoli.
2. A laryngospasm, a mucus plug, fluid, or foam blockage in the airway causes a vacuum effect in the alveoli, causing fluid to be pulled into the alveoli from the pulmonary capillaries.
3. Alveoli walls are damaged, increasing their permeability, which allows fluids from the pulmonary capillaries to enter the alveoli.
4. Saltwater is three times saltier than our blood. If saltwater enters our alveoli, it will pull fluid from the pulmonary capillaries into to the alveoli through the process of osmosis to equalize the salt concentration. Now the alveoli contain both the saltwater and additional fluid from the blood.
5. Freshwater is less salty than our blood so if it enters the alveoli, osmosis will rapidly pull it through the alveoli walls into the blood in the pulmonary capillaries. From there it will become part of our blood volume throughout our body. As it is pulled through the alveoli walls it will destroy the surfactant, resulting in alveoli collapse and damage. Irritated or damaged alveoli fill with fluid from the blood.

As we can see, there are several ways a person can actually die from submersion. The true definition of drowning is death caused by aspiration of fluids in to air passages, as is often seen in the wet drowning. As we have learned, a laryngospasm, bronchiol spasms, and mucus can also cause drowning death plugs. This is sometimes called death-by-submersion, rather than death-by-drowning. For our purposes, we will consider both to be drowning.

Medical Tests for Drowning

It was once believed that fresh and saltwater drownings caused significant blood chemistry changes. These beliefs were the results of research done using dogs who were drowned in submerged metal cages. Later observations on human drowning victims showed that the method of drowning the dogs, and dog physiology were not the same as human drownings. The data obtained from the drowning of these dogs has proved to have little value for human drownings.

If the water a victim was recovered in was highly fluorinated, an autopsy could find that there are high concentrations of fluorine levels in the plasma if death was due to drowning.

Extensive research has been conducted on a diatom test. Diatoms are microscopic algae found in sea water and clean freshwater, that have a very strong siliceous capsule. The thought was that if a person was alive in the water, and inhaled diatom-containing water, then diatoms would be found in the lungs, and possibly in the tissue if the diatoms penetrated through alveolar walls and active circulation takes the diatoms around to various body tissues. If the person is dead, circulation is stopped so the diatoms won't reach the tissues.

The reason the diatom test is controversial is because known drownings often show negative diatom tests, and false positives are also known to occur. New tests are being researched for better results. If better tests can be developed the advantages would be important because then even the bone marrow in skeletal remains could provide evidence for death by drowning.

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