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Electrically Induced Deaths Involving Water Immersion

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The diagnosis of low-voltage electrocution is aided by the presence of electrical burns. When the victim is immersed in water, however, the cooling effect of the water prevents heating of the tissues and eliminates the usual entry and exit points. Cases are described here in which electrical shock and water immersion combined to bring about fatal results. Although electrical shock was instrumental in bringing about these deaths, the actual cause of death in two of the cases was not electrocution, but drowning. The cases demonstrate the need for thorough site investigation, which will assist the pathologist at autopsy and also serve the community by preventing similar deaths at the same death scene.
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The number of fatal electrocutions each year in the United States has been estimated at 1,500, with 500 of these deaths being brought about by consumer products (1). In Dallas County, Texas, ~12 electrical deaths each year are investigated by the Medical Examiner's Office. Deaths in which the deceased was immersed in water while receiving electrical current are less common than normal "on land" electrocutions. The diagnosis of this type of death, in which both electrical current and water immersion are present, is elusive and requires even more investigation than the normal "on land" electrical death.

The difficulty in properly diagnosing an electrical death with water immersion is caused by a lack of electrical burns on the body. Studies by Wright and Davis (2) and by Mellen et al. (3) indicate that low-voltage electrocution victims have burns in ~50–60% of cases examined. Water serves as a natural heat sink and thus works to prevent elevated skin temperatures. Water also serves to lower skin resistance and to lower current density. All of these factors weigh against burns that are typical of low-voltage electrocution victims. Moreover, the cause of death when water and electricity are present may not be electrocution, but rather drowning caused by electrical shock.

CASE REPORTS

Various cases of electrically related deaths with water immersion that I have investigated are described here.

Case 1

The deceased, a 26-year-old pastor who was in front of his congregation, was barefoot and waist deep in a baptismal. The baptismal, at floor level, was made from concrete; later testing revealed the concrete to be well grounded. When the pastor

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grabbed a microphone as it started to tip over, he was fatally shocked. Testing showed that the amplifier fed by the microphone was placing 21 VAC (volts, alternating current) on the case of the microphone. The results of the autopsy were negative for any life-threatening disease process and no burns were found on the body. There was no evidence found to indicate death by drowning.

Case 2

The deceased, a woman in her mid-50's, was found in a bathtub full of water, along with two hair dryers, both plugged into 120-VAC wall outlets. A suicide note that was found indicated that the deceased was ending her life because she had cancer, and autopsy confirmed the presence of this cancer. No burns were found on the body, and there were no signs of drowning.

Case 3

The deceased, a 13-year-old boy, had been swimming in a pool when he began to lose buoyancy and called for help. Persons attempting to enter the pool for rescue purposes reported being shocked. Subsequent testing revealed a defective pool-light fixture that was sending 120 VAC in the pool. At autopsy, it was determined that the deceased died from drowning after being paralyzed by electrical current. No evidence of electrical trauma was found on the body.

Case 4

The deceased, a man in his late 20s, dove into a swimming pool in order to help a child who had difficulty staying afloat. The man was able to get the child out of the water, but was himself unable to leave the pool. The child survived with no injuries, but described being shocked. A defective pool light was energizing the pool at a level of 120 VAC. At autopsy, the cause of death was determined to be drowning, secondary to electrical current exposure.

DISCUSSION

In these cases, the deaths could be classified because of eyewitness testimony (cases 1, 3, and 4) or a suicide note (case 2). An engineering examination of the death scene and of the electrical apparatus confirmed that electrical shock was instrumental in causing these deaths. In cases 3 and 4, however, electrocution was not the cause of death; rather, death was via drowning, which was a consequence of electrical current paralyzing the muscles used for swimming.

Case 1 emphasizes that ventricular fibrillation is brought about by a magnitude of current, and not by voltage level alone. In this instance, the voltage present was 21 VAC, which is often thought of as being safe. On dry land, 21 VAC is usually safe. However, 21 VAC can induce current sufficient to cause muscular paralysis and eventual ventricular fibrillation if the skin's resistance is substantially lowered by the water's presence.

None of the victims in these cases had electrical burns on their body. Electrical burns are caused by focalized heating of tissues, which cannot occur with water immersion. The water serves as a large heat sink and is somewhat conductive, depending upon its ionic content. Besides acting as a heat dissipator, the water decreases the current density through the skin. In case 1, the deceased could have had burns from the microphone on his hand because the hand was not immersed, but the lower torso, fully submerged, would not have had burns.

To create burns while submersed in water, the water requires a temperature of at least ~125°F. After the accident described in case 3, several of the would-be rescuers maintained that they had received electric burns while in the water. Tests of the pool and the light fixture revealed a current flow of 10–12 A from the light fixture through the water. At most, 1,440 W were being dissipated into a heat sink of 30,000 gallons of water. A household water heater often requires nearly 1 h and 4,500 W to raise 50 gallons of water to the same 125°F level. Calculations show that it would be impossible, using 1,440 W, ever to elevate the temperature of the swimming pool to the point where burns would be received.

The deceased in case 2, while bearing no electrical burns, could have received thermal burns, given enough time. The two hair dryers produced 2,500 W of heat, all dissipated into the water. Testing of water in a similar tub with a 2,500-W heater showed that a water temperature of 140°F could be reached in several hours. Had the body not been discovered early, thermal burns consistent with scalding would have been found.

The need for thorough scene investigation and complete autopsy in these types of deaths is illustrated by the following episode. The deceased, a 35-year-old male resident of a nursing home, was prone to seizures and was diagnosed as having organic brain syndrome. A partial corpus callosotomy had been performed, and phenobarbital and dilantin were prescribed in efforts to control the seizures. The deceased was unattended when found in a whirlpool and was then hastily embalmed before an autopsy was performed. There were conflicting reports as to whether vomitus was in the whirlpool

water and as to whether the head was submerged. No electrical burns were present, but subcutaneous hemorrhage was found in the right neck and right chest. The tongue was normal. In this instance, the cause of death could not be determined. Possible causes of death included accidental electrical shock bringing about ventricular fibrillation, electrical shock causing paralysis and leading to drowning, an epileptic seizure, drowning induced by a seizure, or foul play. The alteration of the scene after the accident and the embalming (ordered by the nursing home) prevented the proper investigation of this death.

A second and even more important reason for vigorous investigations of these deaths is to prevent further injury. In case 3, the death occurred during the early evening, with a photocell causing the pool light to be energized after dark. If the deceased had been found still submersed in the pool the next morning, there would have been no reason to suspect an electrical hazard. The death certificate would be accurate, based on autopsy findings, in reporting that the youth had drowned. It would not be until someone else was in the pool at night that the hazard would once again appear, possibly again with fatal results.

Both electrocution and drowning deaths require exclusion of other causes of death. The electrically induced death involving water immersion falls in this same category. If a good swimmer is found dead in a swimming pool, there has to be a reason for the swimmer's loss of mobility and subsequent drowning. A full autopsy with toxicologic analysis may disclose the reason for the drowning or may disclose that the swimmer did not drown at all. If the autopsy fails to reveal evidence of foul play, intoxication, trauma to the head from falling, a natural disease process, or any other reason for the person to have drowned, a check of the pool's electrical system is in order. Because there are no electrical burns in these cases, the only way to exclude electrical paralysis and subsequent drowning is to inspect the system.

The use of ground fault interrupters (GFIs) is now mandated around any part of a home where both electricity and water are present (4). GFIs serve to prevent electrical deaths and would have prevented the deaths in cases 1–4. In case 2, the bathroom plug had a GFI, but the deceased had plugged extension cords for the hair dryers in a neighboring bedroom. The swimming-pool lights in cases 3 and 4 were required by the National Electrical Code to have GFIs, but did not.

In the case of near complete immersion in water, one will have difficulty defining an entry or exit point of the electrical current. The human body represents a volume conductor and will have some electrical resistance. The amount of current flow through the body depends not only on the person, but to a large extent on the shape of the vessel, how it is grounded, where the person physically is in the vessel, and the ionic content of the water. Testing of the pool in case 3 showed that a fault current of 10–12 A flowed into the pool from the defective light, exiting through both the walls of the pool and the plumbing. What additional amount of current will flow from the light when a human enters water under such conditions is not known, but dry-land values show that 10 mA flowing through a human will paralyze the arms of a 150-lb male (5). In real life, the current through a submerged human body will change continuously as the person's position within the vessel changes and as water splashes. Thus, no set answer can be given as to even the average level of current that will flow through a human under such conditions.

All four cases examined were low-voltage electrical incidents, and such cases will certainly be more commonly encountered than high-voltage scenarios. High voltage (>600 VAC) that is used in the United States is typically found in power lines, with its transmission governed by the National Electric Safety Code (NESC) (6). The NESC dictates minimum power-line clearance heights and burial depths, making it unlikely that a power line would be a hazard to a person immersed in water. Instances in which power lines have been associated with injuring persons near water usually relate to the sailing of catamarans on lakes that have power lines overhead; the mast catches the power line, electrifying the mast and boat (7). In these instances, the energization starts before the occupants are spilled into the water. Once the mast is clear of the line, electrification of the vessel ceases.

SUMMATION

The common electrocutions that are a routine part of the pathologist's caseload are dramatically altered by the presence of water immersion. The case studies demonstrate that, due to the heat-sink effect produced, water prevents electrical burns. As such, electrical burns in such cases are not expected. The case studies further show that water immersion may cause death by drowning rather than electrocution. Without eyewitness testimony or other corroborating physical evidence, the determination of the cause of death in these cases will be extremely difficult. The silent and invisible nature of electric current requires thorough investigation of death scenes so as to aid in accurately determining the cause of

death and to ensure that no one else is injured by the same instrumentality.

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