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Pathological perspectives on animal drowning: From external indicators to internal evidence

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Abstract
In forensic veterinary pathology, accurately diagnosing drowning in animals is complex due to the subtlety of pathological changes and the variations in drowning mechanisms. Drowning results from asphyxia caused by fluid obstructing the airways, and effective diagnosis relies on a comprehensive examination of both external and internal signs of fluid aspiration and respiratory compromise. This article reviews the mechanisms of drowning, including dry drowning, post immersion syndrome, hydrocution, freshwater, and saltwater drowning. Each type has distinct pathological features and fatal periods, which help differentiate them during forensic investigations. Internal examination findings such as ballooning of the lungs, emphysema aquosum, oedema aquosum, and Paultouf's haemorrhages, along with ancillary tests like the diatom test and Gettler's test, are crucial for accurate diagnosis.

Keywords: Post immersion syndrome, hydrocution, emphysema aquosum, oedema aquosum, paultouf's haemorrhages

1. Introduction
In forensic veterinary pathology, drowning poses a significant challenge, particularly when determining the cause of death in animals. Drowning is characterized by asphyxia due to the presence of fluid in the airways, which obstructs the normal flow of oxygen and impairs ventilation. The forensic diagnosis of drowning in animals involves a detailed examination of both the external and internal signs of fluid aspiration and asphyxia. This can be particularly complex, as complete submersion is not always necessary; even partial immersion can lead to fatal respiratory compromise. Accurate forensic diagnosis requires a thorough understanding of the pathological changes associated with drowning, as well as careful differentiation from other causes of death. This article explores the forensic techniques and diagnostic criteria used to identify drowning in animals, providing essential insights for veterinarians and forensic pathologists in determining the accurate cause of death.

2. Mechanism of Drowning in Animals
Drowning is a critical condition resulting in asphyxia due to fluid entering and obstructing the airways. The forensic diagnosis of drowning in animals involves understanding the specific mechanisms by which drowning occurs and how it affects the body. The mechanism of drowning in animals is a multifaceted process involving various physiological and physical factors. It begins when an animal falls into water, initially sinking due to gravity. The extent of submersion is influenced by the animal's body weight, the force of the fall, and its inherent buoyancy, with animals possessing greater weight or less buoyancy sinking more rapidly. After submersion, the animal may resurface thanks to its natural buoyancy from air in the lungs and other body cavities, coupled with struggling and limb movement. Upon reaching the surface, the animal often displays intense respiratory efforts, characterized by rapid, deep breaths and forceful coughing to expel air and clear the water from its airways, driven by the panic and lack of oxygen. Each cycle of submersion and resurfacing gradually increases the animal's body weight as air in the lungs is replaced by water, raising its specific gravity. Consequently, the animal repeatedly sinks and surfaces as it attempts to breathe, with each ascent becoming more difficult due to increased weight and reduced buoyancy.

This repetitive cycle continues until the air trapped in the lungs is fully replaced by water. As a result, the animal becomes increasingly exhausted, and its ability to stay afloat diminishes. Eventually, complete exhaustion leads the animal into a state of suspended animation, where the lack of oxygen and inability to resurface result in the cessation of vital functions, culminating in death as the animal remains submerged, unable to recover or escape.

3. Types of drowning

Dry drowning

Dry drowning also known as dry asphyxia, is a condition where asphyxiation occurs without water entering the lungs. This type of drowning is marked by a sustained laryngeal or vocal cord spasm that blocks both water and air from entering the air passage, thereby preventing water from reaching the lungs. The primary issue is the obstruction of the airway, which results in a lack of oxygen reaching the lungs and leads to severe respiratory distress and hypoxia. Despite the absence of water in the lungs, the physiological effects are similar to those of drowning. In forensic veterinary pathology, distinguishing dry drowning involves noting the lack of water in the lungs and identifying the presence of laryngeal or vocal cord spasm while ruling out other causes of death.

Post Immersion Syndrome

Post Immersion Syndrome also known as secondary drowning or near drowning, occurs when an animal or person is rescued and resuscitated after a drowning incident but survives for only up to 24 hours. Despite initial recovery, death may ensue within this period due to secondary complications such as cerebral edema, acute aspirational pneumonia, and cardiac arrhythmia's. These complications arise from the aftermath of the drowning experience and can lead to a gradual deterioration of health, ultimately resulting in death if not promptly and effectively managed.

Hydrocution

Hydrocution also known as immersion syndrome, is characterized by cardiac arrest resulting from reflex vagal inhibition, a condition often reported in human medicine. This syndrome is commonly associated with sudden immersion in cold water. Activities such as diving into cold water, particularly duck diving (diving feet first), or experiencing waves of water hitting the hypogastrium or lower part of the body, including the scrotum in males, can precipitate this response. The abrupt exposure to cold water triggers a reflex that can lead to severe cardiac disturbances and immediate cardiac arrest. Such cases have been documented in human medicine, highlighting the serious risks associated with sudden cold water immersion and its potential to cause rapid cardiovascular collapse.

Freshwater drowning

Freshwater drowning occurs in water with a salinity of 0.6% NaCl (hypotonic water). When freshwater enters the air passages and reaches the alveoli, it triggers a significant physiological response. The salinity of the water is lower than that of the blood, which has a salinity of 0.9-1%. As a result, a large volume of water moves from the alveoli into the pulmonary circulation, leading to hypervolemia and haemodilution. Within three minutes of submersion, and likely less than two minutes after inhalation, the body can contain approximately 72% drowning fluid. The resulting haemodilution causes red blood cells to swell and haemolyze, releasing large quantities of free hemoglobin into the plasma. As erythrocytes lyse, potassium is released, leading to a considerable increase in plasma potassium levels, while sodium concentrations decrease, resulting in a significant rise in the K/Na ratio. This electrolyte imbalance is more dangerous than the overall changes in blood tonicity. The coronary circulation, exposed to this abnormal blood and severe anoxia, places the myocardium under biochemical stress, leading to ventricular fibrillation within minutes. Excessive fluid overload further contributes to cardiac disturbances, and extreme pulmonary vasoconstriction, similar to acute anaphylactic shock, may also occur as the lungs become flooded. The initial hypervolemia increases the heart's pumping capacity abruptly, which can lead to cardiac arrhythmia. These arrhythmias can progress to ventricular tachycardia and fibrillation due to elevated potassium levels (hyperkalemia), reduced sodium levels (hyponatremia), and decreased calcium levels (hypocalcemia) from the hemolyzed blood. Following death from drowning, the right ventricle is typically found distended, while the left ventricle is contracted and almost empty. This combination of haemodilution, electrolyte disturbances, and cardiac strain ultimately leads to fatal arrhythmia and death.

Saltwater drowning

Saltwater drowning occurs when individuals inhale water with a salinity of around 3.5% NaCl, creating a hypertonic environment in the lungs compared to the blood's salinity of 0.9-1.1%. This significant disparity in salinity causes water to move from the pulmonary circulation into the alveoli, leading to haemoconcentration in animals without altering the potassium-sodium ratio. This fluid accumulation in the lungs results in pulmonary edema and subsequent swelling, which impairs gas exchange and leads to asphyxia. The hypertonic condition also causes shrinkage of blood cells, contributing to hypernatremia (elevated sodium levels) and hypokalemia (reduced potassium levels). In dogs, research has reported that heart failure in saltwater drowning typically occurs gradually within 5-8 minutes, without the occurrence of ventricular fibrillation. Humans experience less pronounced haemoconcentration but show similar physiological disturbances, particularly the build-up of fluid in the lungs and subsequent asphyxiation. Research suggests that the heart failure observed is likely due to prolonged and severe myocardial anoxia, exacerbated by pulmonary edema. The onset of heart failure in saltwater drowning appears to be primarily due to myocardial anoxia. Additionally, both saltwater and freshwater drowning are marked by severe pulmonary edema with plasma exudation into the alveoli, contributing to the tenacious froth often found in the airways during drowning cases. In terms of timing, saltwater drowning typically results in death within 8-10 minutes, while freshwater drowning causes death more rapidly, within 4-5 minutes. These time frames are critical, as they represent the window within which physiological disruptions become irreversible.

4. External postmortem findings

In forensic examinations of drowning cases in animals, specific postmortem findings provide critical insights into the circumstances surrounding death. External findings such as the presence of froth in the nostrils and cadaveric spasm are particularly indicative of antemortem drowning. Froth is characterized by white, copious material that can be seen emerging from the mouth and nostrils and reappears upon wiping, a result of water stimulating the mucosal lining of the bronchi and trachea, leading to the production of mucus and surfactant. This frothy substance does not easily collapse when touched due to the surfactant lining. Cadaveric spasm, the immediate and persistent muscle contraction upon death, is also a notable finding. Other external changes, like cutis anserina (goose flesh) and waterman's hands or feet, are less specific and can be present in both antemortem and postmortem drowning. Cutis anserina, where the hair stands erect due to contraction of the erector pili muscles, is observed in both types of drowning, while washerman's hands or feet, characterized by swollen, bleached, and wrinkled skin, is not typically seen in animals. In animals such as mammals and birds, drowning is less common in antemortem scenarios unless influenced by natural flood conditions, which can present an unnatural cause of death.

5. Internal postmortem findings

In the internal examination of drowning cases, several critical findings are assessed to differentiate antemortem drowning from postmortem changes. The lungs typically exhibit ballooning, characterized by their voluminous and distended appearance, with pronounced rib markings visible on their lateral surfaces. To avoid accidental puncture during examination, the carcass is often opened at the sternum. Emphysema aquosum, seen in approximately 80% of human drowning cases and reported in human forensic medicine, indicates water entry into the lung tissue due to alveolar wall rupture, a finding specific to antemortem drowning. Oedema aquosum represents passive water entry into the lungs without froth formation, often observed in unconscious individuals submerged in water. This also reported in human forensic cases. Paultouf's haemorrhages, characterized by multiple shining, bluish or bluish-red spots subpleurally in the lower lung lobes, result from alveolar wall rupture and intrapulmonary hemorrhages. These haemorrhages are documented in human forensic medicine.

When differentiating between freshwater and seawater drowning, notable differences are evident (Described in Table-1). In freshwater drowning, the lungs are ballooned but not heavy, and the lung consistency is emphysematous with retained shape after removal. In contrast, seawater drowning results in heavier lungs that are soft and jelly-like, and the lungs tend to flatten post-removal. Freshwater drowning typically produces crepitus upon cut section with less froth, whereas seawater drowning shows copious froth and no crepitus. (Table-1)

Table 1: When differentiating between freshwater and seawater drowning, notable differences are evident

S. No	Criteria	Freshwater	Sea water
1	Weight of lung	Ballooned, not heavy	Heavy
2	Consistency of lung	Emphysematous	Soft and jelly like
3	Shape of lungs after removal from body	Shape retained	Tends to flatten
4	Cut section	Crepitus heard Froth less	No crepitus Copious froth

Additional internal findings include voluminous lungs that initially present crepitations, later changing to a spongy consistency with emphysema aquosum. Specific changes for antemortem drowning include the presence of mud in the airway and lower airways, water in the stomach, and water in the middle ear. In approximately 70% of cases, water is found in the stomach, with its chemical and microscopic nature matching the medium where the body was discovered. Water in the stomach, especially if it is unpalatable or undrinkable, is suggestive of antemortem drowning. Similarly, water in the intestines, observed in about 20% of cases, supports the diagnosis of antemortem drowning. Additionally, water and hemorrhages in the middle ear, mastoid process, and temporal bone further indicate drowning.

6. Diagnosis

Accurate diagnosis of drowning in forensic veterinary pathology involves a combination of observational and ancillary tests to distinguish antemortem drowning from postmortem changes. Drowning, a complex process leading to asphyxia, can be challenging to diagnose due to the subtle and varied pathological changes it induces. The examination of internal findings, including lung condition and the presence of specific physical changes, provides critical clues. However, ancillary tests such as the diatom test and electrolyte analysis offer additional, crucial evidence.

6.1 Diatom Test: Diatoms are unicellular algae with siliceous cell walls that are highly resistant to acid, alkali, high temperature and enzymatic digestion. During antemortem drowning, inhaled diatoms enter the lungs and are subsequently circulated to peripheral organs through the bloodstream. Detection of diatoms in these peripheral organs, such as the femoral bone marrow, spleen, and brain, is indicative of antemortem drowning. The presence of diatoms in the lungs alone, without corresponding findings in peripheral organs, suggests postmortem drowning. The most effective specimens for diatom detection are the bone marrow from the femur and sternum. Testing methods include direct lung examination, incineration test, and acid digestion test.

6.2 Electrolyte Test (Gettler's Test): This test measures chloride concentration in the heart chambers to help differentiate between freshwater and seawater drowning. In cases of freshwater drowning, the chloride concentration is typically higher in the right side of the heart because the left side receives diluted blood. Conversely, in seawater drowning, the left side of the heart shows higher chloride levels due to hyper-concentrated blood. A significant difference in chloride levels between the right and left sides of the heart greater than 85% suggests antemortem drowning. Additionally, elevated sodium levels in the vitreous humor can indicate saltwater drowning, while decreased sodium levels suggest freshwater drowning, although this marker requires further validation.

7. Conclusion

Diagnosing drowning in animals necessitates a multifaceted approach involving detailed pathological examination and ancillary tests. The external signs, such as the presence of froth and cadaveric spasm, along with internal findings like lung ballooning and specific hemorrhages, are critical for differentiating drowning from other causes of death. The observed differences between freshwater and seawater drowning in lung characteristics and electrolyte levels offer further diagnostic clues. Ancillary tests, including the diatom test and electrolyte analysis, provide additional evidence to support the diagnosis of antemortem drowning. Understanding these diagnostic criteria and their application is essential for forensic veterinary pathologists to accurately determine the cause of death in suspected drowning cases.

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