Drowning is the third leading cause of accidental death and the second most common cause of death in people younger than age 44 years. Similar statistics are not available for animals, but it is speculated that this syndrome is also an important cause of mortality in our pet population. Few reports exist in the veterinary literature, and most of what we know about near drowning is extrapolated from the human literature.

Drowning is broken into two distinct syndromes: immersion syndrome and submersion syndrome (see the box on page 2). More than 85% of drowning accidents involve aspiration of water into the lungs. The other 15% of cases may still suffer from pulmonary injury. Water aspirated into the pharyngeal area may stimulate laryngeal spasm. Further attempts at respiration may induce the formation of negative pressure pulmonary edema (noncardiogenic). The intrathoracic pressure changes can lead to an increase in intrathoracic blood volume and pulmonary artery pressure and a decrease in pulmonary interstitial pressure. These pressure shifts can cause fluid to flow into the interstitium from the vasculature, which, when extensive enough, overflows into the alveoli. This pulmonary pathology can be just as severe as that resulting from large amounts of fluid aspirated into the lungs.

Drowning can occur in fresh or salt water. This distinction is important because the pathophysiology involved in these conditions differs, as do the possible consequences and optimal treatment. Compared with plasma, fresh water is hypotonic. When aspirated into the lungs, this fluid is absorbed into the bloodstream, causing hemodilution and possible hyponatremia and hypokalemia. The resultant change in plasma tonicity and electrolyte abnormalities can lead to secondary red cell hemolysis. This hemolysis by itself can impair oxygen delivery to the tissues. Fresh water, in addition to the hemodilution, also inactivates the surfactant within the alveoli. This alters alveolar surface tension and can result in alveolar collapse and pulmonary atelectasis. The ventilation/perfusion mismatch caused by perfused but unventilated lung regions causes hypoxemia, which can be severe. This can be potentiated by the mere presence of water in the alveoli and interstitium, acting as a diffusion barrier. This intrapulmonary shunting and barrier to oxygenation of the blood further hampers oxygenation of the tissues.

In contrast, salt water pulls fluid into the alveoli because of its hypertonicity. This fluid comes from the vasculature, and if significant enough, it can cause a depletion of the intravascular fluid volume. Hypovolemia, hemoconcentration, and hypotension may result. This, in turn, can lead to decreased tissue perfusion and tissue hypoxia. Salt water does not inactivate the surfactant, so atelectasis is not typically a component of this syndrome. The electrolyte abnormalities involved in salt water aspiration are primarily hypernatremia, with a possible increase in serum calcium and magnesium based on the mineral content of the water. Despite the initiating physiology, the end pathology

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associated with drowning results in systemic hypoxemia. This is manifested primarily as respiratory and neurologic problems. The original injury to the lungs may also incite an episode of acute respiratory distress syndrome, further complicating the hypoxemia. This decreased oxygen, especially when associated with potential hypovolemia, can lead to tissue damage. The main tissues of concern are the heart, brain, and kidneys. Any ischemia to these areas as well as others can lead to organ failure and death.

Early and aggressive therapy is paramount in treating near-drowning victims. The main objectives are to support oxygenation and perfusion to tissues and to decrease intracranial pressure (ICP) while maintaining cerebral perfusion. The degree of cerebral damage is the major limiting factor related to survival; however, with this in mind, each case should be treated and evaluated individually.

**DIAGNOSTIC CRITERIA**

**Historical Information**

**Gender Predisposition**
- Males are more predisposed to drowning in the human population; however, similar statistics are unavailable for veterinary patients.

**Age Predisposition**
- In humans, 60% of drowning deaths are in children or adolescents younger than age 20 years; no apparent age predisposition is recognized in animals.

**Owner Observations**
- Owners have often witnessed the near-drowning event, in some cases even rescuing their pet from the water and initiating resuscitative efforts.
- If the actual event is not witnessed, the animal may be found near a body of water with evidence of submersion (e.g., wet hair coat; animal surrounded by a puddle of water).

**Other Historical Considerations/Predispositions**
- Humans with a seizure history are four times more likely to suffer submersion accidents. Although this correlation has not been proven in animals, the possibility of an underlying neurologic issue should be considered.

**KEY TO COSTS**

$ indicates relative costs of any diagnostic and treatment regimens listed.

$ costs less than $250

$ costs between $250 and $500

$ costs between $500 and $1,000

$ costs more than $1,000
Physical Examination Findings
• The level of consciousness at presentation is a key prognostic indicator paramount to patient evaluation in human medicine. Although this has yet to be fully validated for veterinary patients, it should still hold true physiologically. Animals with normal mentation should have a more favorable prognosis, and those with mentation changes have a more guarded prognosis and require careful monitoring and evaluation.
• Respiratory distress.
• Increased lung sounds or crackles on thoracic auscultation.
• Hypothermia (temperature below 99.5°F or 37.5°C).
• Pallor or cyanosis.

Laboratory Findings

Complete Blood Count $• Can be normal.
• Anemia, dilutional or hemolytic (reference range, 37%–45%) in fresh water drowning.
• Hemoconcentration in salt water drowning.
• A stress leukogram may be present, characterized by a mature neutrophilia (reference range, 3,000–11,400/µl), lymphopenia (reference range, 1,000–4,000/µl), monocytosis (reference range, 150–1,350/µl), and eosinophilia (reference range, 0–1,500/µl).
• Platelets may be low if organ systems are starting to fail (reference range, 165,000–500,000/µl).

Chemistry Panel $• Low sodium (reference range, 146–160 mEq/L) and low potassium (reference range, 3.5–5.9 mEq/L) with fresh water drowning.
• High sodium and chloride (reference range, 108–125 mEq/L) with salt water drowning.
• May see high calcium (total reference range, 9.5–11.8 mg/dl; ionized reference range, 1.2–1.4 mg/dl) or magnesium (ionized reference range, 0.4–0.55 mg/dl), depending on the mineral content of the water aspirated.
• Azotemia may be present (creatinine reference range, 0–1.3 mg/dl; urea nitrogen reference range, 10–25 mg/dl) as a prerenal component with salt water drowning and hypovolemia or as a primary renal component with secondary organ failure.
• Liver enzymes may be elevated (alkaline phosphatase reference range, 4–95 U/L; alanine aminotransferase reference range, 26–200 U/L) because of hypoxic injury or with secondary organ failure.

Urinalysis $• Isosthenuria or hypothenuria (normal specific gravity reference range, 1.012–1.035) may be present with fresh water drowning.

Other Diagnostic Findings

Thoracic Radiography
• Diffuse interstitial to alveolar pattern.
• Infiltration centered caudodorsal in patients with negative pressure pulmonary edema.
• Increased vasculature with possible perihilar edema in patients with fresh water aspiration and volume overload.
• Can be normal.

Electrocardiography
• Arrhythmias may be present, especially during rewarming. The most common arrhythmias associated with rewarming, hypoxemia, or electrolyte abnormalities in animals are atrial or ventricular fibrillation, premature ventricular contractions, and ventricular tachycardia.

Summary of Diagnostic Criteria
• Known submersion.
• Respiratory distress.
• Interstitial to alveolar pattern on thoracic radiographs.
• Hypoxemia with either increased A–a gradient or decreased PaO$_2$:FiO$_2$ ratio.

Diagnostic Differentials
Cardiogenic Pulmonary Edema
• History of cardiac disease.
• Presence of cardiac murmur or arrhythmia.
• Thoracic radiography shows evidence of enlarged left atrium and venous congestion. Interstitial to
Initial Treatment

Intravenous Fluid Resuscitation
- The need for and aggressiveness of fluid therapy is varied in these patients. Those suffering from fresh water drowning are more likely to be volume overloaded on presentation, and they may not need any fluids. Salt water victims tend to be hypovolemic, therefore benefiting from fluid administration. Rates should be based on clinical status, with animals in shock or decompensated animals resuscitated more aggressively with crystalloid or colloid fluids.
- The choice of fluid should be based on electrolyte abnormalities. If hyponatremia is present, 0.9% NaCl should be used if it is deemed that fluids are necessary. Hypernatremia typically indicates loss of free water and a dehydrated state; therefore, a balanced electrolyte solution (e.g., lactated Ringer’s solution, Normosol-R, Plasmalyte) should be used to replace the deficit. Correction of sodium derangements should be completed slowly after the animal is rehydrated to allow for reequilibration of osmoles within the brain parenchyma, typically no faster than 0.5 mEq/hr. Potassium can also be supplemented in the fluids as needed to maintain a normal serum level.

Oxygen Administration
- An enriched oxygen environment is often needed to treat hypoxemia (PaO$_2$ <80 mm Hg or percent oxygen saturation [SpO$_2$] <92%). An oxygen flow-by or face mask can be used initially while the patient is being stabilized as long as it does not place undue stress on the animal. A nasal oxygen cannula can be placed or oxygen can be administered through an oxygen hood or via an oxygen cage.
- Mechanical ventilation is indicated in patients with a PaO$_2$ of <60 mm Hg despite oxygen supplementation. Other criteria include a PaCO$_2$ of >60 mm Hg and an excessive effort to breathe that will eventually tire out the animal. Animals using ventilators need to be very closely monitored, and the FiO$_2$ must be kept at a minimum value that maintains an adequate PaO$_2$ in order to avoid oxygen toxicity. Positive end-expiratory pressure can be implemented to help lower the FiO$_2$ while maintaining PaO$_2$.
- Continuous positive airway pressure is another method that can help optimize oxygenation attempts. This can be used with a ventilator or a nasotracheal oxygen cannula.

Rewarming
Rewarming should be done slowly. Careful monitoring of the patient’s temperature, electrocardiogram, and volume status is vital. Three methods of rewarming can be used, depending on the severity of hypothermia:
• **Passive external rewarming** is used for mild hypothermia (96°F to 99°F). This is accomplished by simply placing blankets over the animal and allowing its own body heat to warm it up.

• **Active external rewarming** is used for more serious hypothermia treatment (85°F to 96°F). External heat is used with the animal covered to increase its body temperature. Sources of external heat include a warm-water blanket, forced-air heating blanket, or a warming light.

• **Core rewarming** is the most aggressive rewarming strategy and is reserved for severe cases of hypothermia (<82°F). This involves instillation of warm saline into the peritoneal or pleural cavities, warm-water enemas, or gastric lavage.

**Alternative/Optional Treatments/Therapy**

**Reduction of Intracranial Pressure**

- ICP can be increased in these patients because of cerebral edema from the overhydration or sodium changes or because of cerebral acidosis. $\text{\textsuperscript{1}}$

- **Mannitol** has been proposed to decrease ICP through two separate mechanisms. It is an osmotic diuretic that pulls fluid from the cerebral parenchyma into the vasculature with excretion of this fluid by the kidneys. Secondly and possibly more importantly, mannitol also decreases the viscosity of the blood, resulting in a reflex vasoconstriction by the cerebral vasculature. This decreases ICP by lowering the amount of blood in the cerebral cavity. Mannitol also has a free radical scavenging effect that can help limit the damage to the tissue. The dosage is 0.5 to 1 g/kg IV over 20 minutes repeated up to three times q4–8h depending on neurologic status. $\text{\textsuperscript{1}}$

- **Hetastarch or dextran/hypertonic saline solution** can also help to reduce ICP while maintaining blood pressure to optimize cerebral perfusion (Cerebral perfusion = Mean arterial pressure – ICP). This combination may have a greater and longer-lasting effect on reducing ICP than mannitol. The dosage is a total of 5 to 10 ml/kg IV over approximately 5 to 10 minutes; two-thirds of this volume is hetastarch or dextran, and the remaining one-third is the hypertonic saline (7%) solution. The practitioner may want to consider a continuous-rate infusion of hetastarch to follow. $\text{\textsuperscript{1}}$

**Diuretics**

- Furosemide may be helpful in removing some of the pulmonary edema in fresh water drowning. Edema from salt water drowning is more likely to be resistant to the effects of furosemide caused by the increased tonicity within the alveoli from the saline content of the aspirated water. The dosage is 2–6 mg/kg IV, IM, or PO q8–12h or more frequently if needed. If furosemide is used, a close eye should be kept on hydration status and electrolytes.

**Antiarrhythmic Agents** $\text{\textsuperscript{1}}$

- May be indicated to control cardiac arrhythmias associated with rewarming, myocyte hypoxia, or electrolyte abnormalities, among other causes.

- Specific agents and indications for initiation of therapy are beyond the scope of this article, and readers are directed to a more extensive discussion of this topic from a different source.

**Antibiotics** $\text{\textsuperscript{1}}$

- Recommended for use when known aspiration of bacterial contaminated water was aspirated.

- Ideally, a culture of the lower airways (via bronchoalveolar lavage or transtracheal wash) should be obtained and antibiotic choice based on culture and susceptibility results.

**Supportive Treatment**

- **Oxygen therapy** is typically beneficial. This can be administered through various methods, including an oxygen cage, oxygen hood, nasal oxygen line, or mechanical ventilation. The method chosen should not place undue stress on the patient, and the minimum concentration of oxygen that maintains oxygenation should be used to decrease the risk of oxygen toxicity.

- It is important to maintain hydration status, but IV fluids should be used cautiously. These patients can run the risk of overhydration because of the aspiration of large volumes of fresh water. Fluid therapy tailored to maintain a central venous pressure (CVP) of 3 to 5 cm H₂O is recommended.

- **Nutritional management** is important in recovery. If the patient is not voluntarily eating by 3 to 5 days after submersion, more aggressive feeding attempts should be made. These may include syringe feeding if the animal takes it well or placement of a nasesophageal (NE) or esophagostomy feeding tube. The NE tube, although only intended for short-term use, has the benefit of placement without anesthesia. Patients in any of these situations should be monitored for vomiting, with discontinuation of feeding and investigation of and treatment for vomiting as appropriate.

**Patient Monitoring**

- **Serum electrolytes** should be monitored closely, especially if initial derangements were present or if the patient is receiving multiple doses of furosemide.

- **Arterial blood gas** should also be monitored closely, with the calculation of A–a gradient or PaO₂/FiO₂ ratio to monitor progression. Prognosis is poor if the blood gas indicates a need for mechanical ventilation or if there is no sign of improvement in oxygenation in the initial 24 to 48 hours of treatment.
• **Organ function parameters:** Chemistry panel, coagulation profile, and blood pressure should be checked frequently to monitor for secondary organ system failure.

• **CVP** measurement is helpful in the management of fluid administration and should be checked frequently until it stabilizes at 3 to 8 cm H2O.

• **Electrocardiography**, with continuous or intermittent checks throughout the day, should be used to monitor for arrhythmias.

• **Neurologic status** can be monitored with a modified Glasgow Coma Score. This allows a more objective method of monitoring neurologic function to determine if the patient is improving. Worsening or indication of poor neurologic function is associated with a poor prognosis.

**Home Management**

• Continued monitoring of neurologic function (e.g., mentation, seizures, sight, ataxia) and respiratory status.

• Avoidance of bodies of water.

• Continuance of appropriate nutritional support.

**Milestones/Recovery Time Frames**

• Recovery of surfactant function takes approximately 48 to 72 hours. This is more important in fresh water drowning because a dilution of surfactant leading to the clinical signs is associated with this condition. Salt water drowning does not have the same degree of surfactant impairment, so this recovery time frame is not as vital.

• As with other severe pulmonary diseases, lack of improvement or worsening of ventilation over the first 48 hours, as evaluated with arterial blood gas measurements, indicates a poor to grave prognosis.

• Mentation abnormalities should show an improvement within the first 24 to 48 hours. Persistence of abnormalities tends to carry a worse prognosis for recovery.

**Treatment Contraindications**

• Hypertonic saline resuscitation should be avoided in patients with hypernatremia.

• Mannitol should be used with caution in patients with an elevated CVP; administration should be avoided when CVP is greater than 8 cm H2O because this can lead to overhydration.

**PROGNOSIS**

**Favorable Criteria (as per Human Medicine Guidelines)**

• Alert on presentation.

• Submersion in cold water.

• Mild to absent pulmonary dysfunction.

**Unfavorable Criteria (as per Human Medicine Guidelines)**

• Obtunded or comatose on presentation.

• Submersion of >5 minutes.

• Initial pH <7.1.

• Fixed and dilated pupils.

• Need for mechanical ventilation.

**RECOMMENDED READING**


