
Geoff G. Heffner, DVM; Elizabeth A. Rozanski, DVM, DACVECC, DACVIM; Matthew W. Beal, DVM, DACVECC; Søren Boysen, DVM, DACVECC; Lisa Powell, DVM, DACVECC; Sophie Adamantos, BVSc, DACVECC, MRCVS

Objective—To determine clinical characteristics, treatments, and outcome in dogs and cats evaluated after submersion in freshwater.

Design—Retrospective case series.

Animals—25 dogs and 3 cats.

Procedures—Medical records were reviewed for signalment; causes, location, and month of submersion; physical examination findings at admission; results of blood gas analysis; treatments administered; duration of hospitalization; and outcome, including evidence of organ failure or compromise.

Results—All submersions involved bodies of freshwater. Fourteen animals were submerged in man-made water sources, 13 were submerged in natural water sources, and the body of water was not recorded in 1 case. Twenty (71%) submersions occurred from May through September. Cause was identified in 16 animals and included extraordinary circumstances (n = 6), falling into water (6), breaking through ice (3), and intentional submersion (2). Twelve animals were found submerged in water with unclear surrounding circumstances. Treatment included administration of supplemental oxygen, antimicrobials, furosemide, corticosteroids, and aminophylline and assisted ventilation. Respiratory dysfunction was detected in 21 animals. Neurologic dysfunction was detected in 12 animals, hepatocellular compromise was detected in 6 animals, and cardiovascular dysfunction was detected in 4 animals. Three dogs had hemotologic dysfunction, and 2 dogs had acute renal dysfunction. Eighteen (64%) animals survived to hospital discharge, but all of the cats died. In 9 of 10 nonsurvivors, respiratory tract failure was the cause of death or reason for euthanasia.

Conclusions and Clinical Relevance—Results suggest that submersion is an uncommon reason for veterinary evaluation but is associated with a good prognosis in dogs in the absence of respiratory tract failure. (J Am Vet Med Assoc 2008;232:244–248)

Drowning results in approximately 4,000 human deaths each year in the United States, 40% of which involve children younger than 4 years of age.1,2 Reported systemic complications after submersion (drowning) include severe metabolic acidosis, severe hypothermia, rhabdomyolysis, respiratory failure, cardiovascular dysfunction, neurologic damage, and acute renal insufficiency.3-5

Little information has been published regarding clinical findings, treatments, and outcome for companion animals after submersion. To the author’s knowledge, experimental studies and case reports6-11 constitute the only published material regarding submersion in animals. Knowledge of the clinical course of events surrounding submersion would be helpful to clinicians in enabling better care for affected animals and providing better grounds for determining prognosis. The purpose of the present study is to describe the clinical characteristics, treatments provided, reported complications (including development of organ compromise), and outcome in small animals evaluated after submersion in freshwater.

Materials and Methods

Case selection—The medical record databases at 5 veterinary teaching hospitals4 were searched for dogs and cats that were evaluated after a submersion event from January 1996 to December 2005. Records were included if the medical aspects of the record were complete and there was a history of submersion or immersion. Records of animals that were declared dead on arrival at the hospital were excluded because of insufficient historical data.

Medical records review—Data retrieved from the medical record included signalment, causes or potential causes of submersion, location of submersion, month of year, physical examination findings at admission, results of blood gas analysis, treatments administered, duration of hospitalization, and outcome. Records were
also reviewed for evidence of organ compromise; organ systems evaluated included the respiratory tract, nervous system, cardiovascular system, kidneys, and liver; and hematologic changes were also evaluated.

The respiratory tract was considered dysfunctional if \( \text{PaO}_2 \) was < 60 mm Hg, oxygen saturation was < 90%, \( \text{PaCO}_2 \) was > 50 mm Hg, or the animal was in moderate to severe respiratory distress. Neurologic dysfunction was diagnosed if abnormal mentation, including dullness, stupor, or coma, was noticed at any time during hospitalization. Cardiovascular dysfunction was defined as development of arrhythmia or hypotension (systolic pressure < 90 mm Hg). Renal dysfunction was defined as an increase in serum creatinine concentration of 0.5 mg/dL or greater or an increase in BUN concentration to at least twice the highest reference range value during the course of hospitalization. Hematologic dysfunction was defined as abnormally long clotting times (prothrombin time or activated partial thromboplastin time > 125% of reference value), platelet count < 80,000 platelets/μL, or detection of petechiation or ecchymosis. Hepatocellular compromise was defined as serum activities of alkaline phosphatase, alanine aminotransferase, or aspartate aminotransferase > 3 times the upper limit of the reference range or total bilirubin concentration above reference range.

Statistical analysis—Descriptive statistics were used where appropriate. Data for survivors and nonsurvivors were compared by means of \( \chi^2 \) analysis, with values of \( P < 0.05 \) considered significant. Non-survivors included animals that died and those that were euthanized.

Results

Twenty-eight cases from the 5 centers were evaluated in the study; animals included 25 dogs and 3 cats. Age ranged from 2 months to 15 years, with a median age of 3 years. Sixteen animals were males (10 sexually intact and 6 castrated), and 12 were females (2 sexually intact and 10 spayed). Affected dog breeds included Golden Retriever (\( n = 5 \)); mix (4); Great Dane (2); Saint Bernard (2); Boston Terrier (2); and 1 each of Brittany Spaniel, Boxer, English Bulldog, English Springer Spaniel, French Bulldog, Labrador Retriever, Miniature Poodle, Miniature Schnauzer, Rottweiler, and Shih Tzu. Two cats were domestic shorthairs, and 1 was a domestic longhair.

Cause—Twelve animals, including all 3 cats, were found in water without a clear indication of the circumstances associated with the submersion. Causes for submersion were reported in the remaining 16 animals. Five dogs, including 1 with proprioceptive ataxia, fell into water and were apparently unable to swim. Three dogs fell through ice into partially frozen rivers or lakes. Two dogs were intentionally submerged, 1 by a young child in a bathtub and 1 by an unidentified individual. One dog that was known to be a strong swimmer got its feet entrapped in mud beneath the surface after jumping into water. One dog received electric shock in the pool from a power cord. One dog with a permanent tracheostomy voluntarily jumped into water. One dog was trapped beneath a pool cover. One dog had a prolonged seizure (status epilepticus) while swimming. The final dog collapsed while undergoing physical therapy in a rehabilitation pool. This dog was later found to have an adrenal mass that was thought to be responsible for ventricular arrhythmias, hypertension, and subsequent collapse.

Location—All submersion cases took place in freshwater. Location of the submersion was recorded for 27 animals, with 14 occurring in man-made sources and 13 occurring in natural freshwater bodies. Natural freshwater submersion occurred in lakes, ponds, or rivers. Of the 14 submersions that took place in man-made water bodies, 12 occurred in swimming pools, 1 occurred in a physical therapy pool, and 1 occurred in a bathtub.

Time of year—Month of submersion was recorded for all 28 animals. Twenty (71%) submersions occurred in the summer months, from May through September.

Initial physical examination findings—Rectal temperature was recorded in 27 animals. Rectal temperature was too low to register in 3 animals, and temperature was not recorded in 1 animal. Rectal temperatures ranged from 33.6°C (92.5°F; median, 37.8°C [100.0°F]). The dog with the highest rectal temperature had an episode of status epilepticus while swimming, and it was suspected that the seizure was the cause of the hyperthermia. Heart rate was recorded in 26 animals. In dogs, heart rate ranged from 80 to 250 beats/min (median, 140 beats/min), and in cats, heart rate ranged from 54 to 150 beats/min (median, 96 beats/min). Respiratory effort was recorded in all 28 animals at admission. Respiratory effort was characterized as normal (\( n = 4 [14\%] \)) or mildly (7 [25%]), moderately (12 [43%]), or severely (4 [14%]) increased. One animal was taking agonal breaths at the time of admission and did not survive.

Blood gas analysis—Blood pH was recorded in 23 animals and ranged from 7.115 to 7.549. Ten animals were acidic (\( \text{pH} < 7.36 \)), 7 had a pH within reference range (7.36 to 7.44), and 6 were alkaline (\( \text{pH} > 7.44 \)). Alkalosis in those 6 dogs was respiratory in origin, with a median \( \text{PCO}_2 \) of 19.5 mm Hg (reference range, 36 to 46 mm Hg). Arterial blood gas analysis was performed in 11 animals. The fraction of inspired oxygen (\( \text{FiO}_2 \)) at the time of blood gas analysis was recorded in 8 of those animals. Median \( \text{PaO}_2/\text{FiO}_2 \) ratio was 232.5 (range, 135 to 425; reference range, > 475). In the 6 animals that were breathing room air when the arterial blood sample was collected, the median calculated alveolar-arterial oxygen gradient was 50 (range, 26 to 78; reference range, < 15). None of the 11 animals in which arterial blood gases were measured had high \( \text{PCO}_2 \) values.

Treatment—Treatments administered included supplemental oxygen (\( n = 21 \) animals [75%]), 1 or more doses of antimicrobials (19 [68%]), 1 or more doses of furosemide (12 [43%]), assisted ventilation (4 [14%]), 1 or more doses of corticosteroids (3 [11%]), and 1 or more doses of aminophylline (2 [7%]).

Organ compromise—Evidence of organ compromise was detected in 26 animals. Lungs were the most commonly affected organ, with respiratory tract dys-
function reported in 21 (75%) animals. Oxygen supplementation was provided to all animals with respiratory distress. Duration of oxygen supplementation ranged from 0.25 to 168 hours (median, 33.5 hours). Ventilation was assisted with intermittent positive-pressure ventilation in 4 animals. Two cats received manual intermittent positive-pressure ventilation (for 15 minutes in 1 cat and for 2 hours in the other cat) before death. Two dogs received mechanical intermittent positive-pressure ventilation (for 24 hours in 1 dog and for 5 days in the other dog). One dog died, and the other was euthanized after 5 days of ventilatory support without improvement. Pulmonary histopathologic findings in the nonsurviving dog revealed changes consistent with acute respiratory distress syndrome, including alveoli filled with degenerative inflammatory debris and hyaline membranes. Necropsy was not performed in the remaining nonsurvivors.

Respiratory distress was hypothesized to be caused by pneumonia or acute lung injury in 15 animals on the basis of clinical and reported radiographic criteria. Aerobic bacterial culture of airway fluid samples was performed in 4 animals. Three of those samples yielded no growth, and Pasteurella multocida was isolated from 1 animal.

Level of consciousness (ie, mentation) was described in all 28 animals, and neurologic dysfunction was diagnosed in 12 animals at the time of admission. Level of consciousness was described as normal (n = 16 [57%]), decreased (5 [18%]), stuporous (4 [14%]), or comatose (3 [11%]). Twelve of the animals with normal mentation at admission survived. Three animals with decreased mentation, 2 that were stuporous, and 1 that was comatose survived. Of the 16 animals with normal mentation, 7 had a rectal temperature < 38°C (100.5°F). Of the 12 animals with decreased mentation of any severity, 10 had a rectal temperature < 38°C. No surviving animals had neurologic deficits at the time of hospital discharge.

Hepatocellular compromise was detected in 6 animals. Results of serum biochemistry analyses were available for review in only 9 animals. Serum alkaline phosphatase activity was high in 1 animal, alanine aminotransferase activity was high in 3 animals, and aspartate aminotransferase activity was high in 6 animals. High liver enzyme activities may have reflected hypoxemia or lobular necrosis. Total bilirubin concentration was high in 2 animals, both of which concurrently had high values for 1 or more serum liver enzyme activities.

Cardiovascular dysfunction was detected in 4 (14%) animals. One of the dogs was hypotensive at the time of admission. Blood pressure normalized in response to an IV bolus of fluids, and the dog survived to discharge. Three animals had intermittent or sustained ventricular tachycardia with a heart rate > 130 beats/min. No animals with arrhythmias survived.

Hematologic dysfunction was detected in 3 dogs. Critical illness or injury, including hypoxemia, vascular stasis, and acid-base disturbances, may predispose dogs to development of disseminated intravascular coagulation. In 1 dog that was subsequently euthanized, diffuse petechiation was found on physical examination, although a platelet count or platelet function test was not performed. In 2 other dogs, coagulopathy was diagnosed on the basis of prolonged prothrombin time or partial thromboplastin time (times longer than 125% of reference value). One of the dogs with prolonged clotting time survived; that dog had a prothrombin time of 9.8 seconds (reference value, 5.6 seconds) and a partial thromboplastin time of 28.3 seconds (reference value, 11.8 seconds). The dog that died had a prothrombin time of 18.0 seconds (reference value, 6.3 seconds) and a partial thromboplastin time that was outside reference range (reference value, 13.5 seconds). Platelet counts from the same blood samples used to evaluate clotting times were not available in either of the dogs with coagulopathy. Indications of disseminated intravascular coagulation may have been seen in other dogs, but the information was not recorded in the medical record.

Acute renal dysfunction developed in 2 (7%) animals. Blood urea nitrogen and creatinine concentrations were within reference range in both animals at the time of hospital admission, and the highest values were detected 33 hours and 4 days after admission. One dog had improvement in BUN concentration, although the dog died of respiratory failure 120 hours after hospital admission. The other dog had normal BUN and creatinine concentrations at the time of discharge on day 17; that dog was hospitalized for protracted vomiting and inappetence secondary to presumed pancreatitis.

Outcome—Of the 28 animals studied, there were 18 (64%) survivors and 10 (36%) nonsurvivors. Five of the 10 nonsurviving animals were euthanized. Eighteen of the 25 (72%) dogs survived after a median hospitalization time of 2 days (range, 2 hours to 17 days). Nonsurviving dogs had a median hospitalization time of 24 hours (range, 15 minutes to 7 days). All 3 cats died, with hospitalization times of 15 minutes, 14 hours, and 120 hours. In 9 of 10 nonsurvivors, respiratory failure was the cause of death or precipitated the decision for euthanasia. The other animal in the nonsurvivor group was euthanized after an adrenal mass was detected, which was believed to be responsible for collapse, refractory hypertension, and ventricular arrhythmias.

No significant differences between surviving and nonsurviving animals were seen with regard to temperature, heart rate, respiratory effort, mentation, or blood pH at admission. Additionally, no significant differences in duration of oxygen supplementation or hospitalization were seen between surviving and nonsurviving animals.

Discussion

This study was undertaken to determine the clinical and biochemical events associated with freshwater submersion in companion animals. Historically, determination of whether drowning occurred in freshwater or saltwater has been emphasized because the tonicity of the water was perceived to influence outcome. In experimental studies in dogs, aspiration of large volumes of freshwater can induce profound dilutional hyponatremia. This was not observed in animals in the present study, although the actual volumes aspirat-
ed were unknown. In humans that die of drowning in freshwater, the dilution-induced hyponatremia results in hemolysis and characteristic staining of the intima of the aortic arch. However, in recent years, a study of human submersion survivors revealed that water toxicity is substantially less important. Biochemical changes were seen sporadically in the dogs and cats in the present retrospective study. High values for serum liver enzyme activity most likely reflected hepatic hypoxemia or anoxia associated with submersion.

Submersion appears to be a relatively uncommon reason for veterinary evaluation in dogs and cats. The actual frequency of submersion in companion animals is unknown because nonsurvivors or pets that rapidly recover may not be examined at a veterinary hospital. However, knowledge of the clinical and animal characteristics surrounding submersion is important for the clinician.

Not surprisingly, lungs were the most commonly affected organ and respiratory failure was the leading cause of death in nonsurvivors, including 1 animal that developed acute respiratory distress syndrome. Pneumonia or acute lung injury was thought to be the cause for respiratory failure in 15 of the 28 study animals, but these conditions were confirmed in only 2 animals. Pneumonia was suspected on the basis of a pulmonary infiltration pattern seen on thoracic radiographs in most cases. The incidence of pneumonia developing in humans after submersion has been reported to be from 1% to 53%. Caution should be taken in interpreting the incidence of submersion-associated pneumonia in companion animals because this condition can be difficult to diagnose. Aspired fluid, pulmonary atelectasis, or acute lung injury can result in similar radiographic changes that are consistent with pneumonia without pulmonary infection. Some humans with acute lung injury have leukocytosis or fever in the absence of infection. Additionally, positive results of microbial culture can result from active infection, airway colonization, or environmental contamination.

Nineteen (68%) animals in the present study received 1 or more doses of antimicrobials. Infection was confirmed in 2 animals, 1 with microbial growth on a transtracheal aspirate and 1 from histopathologic findings at necropsy. Current guidelines in human medicine recommend avoiding prophylactic use of antimicrobials. This recommendation is made on the basis of findings from retrospective studies in humans revealing that antimicrobial use does not reduce the incidence of pneumonia or improve mortality rate. In patients that developed pneumonia, the pathogen was frequently a multiresistant organism. Given the available data and in accordance with guidelines proposed in veterinary medicine, appropriate samples for culture should be collected prior to initiating antimicrobial treatment if the animal’s clinical stability is not compromised.

Three (11%) animals in the present study received at least 1 dose of corticosteroids. Corticosteroids have traditionally been administered for protection against airway inflammation, but administration of corticosteroids in humans that have been submersed does not change outcome and may predispose to infection. Additionally, a study on the effect of corticosteroid treatment on survival and blood gas exchange in dogs after aspiration of freshwater did not reveal a beneficial effect. Corticosteroid administration is therefore not recommended as part of routine treatment for submersion in veterinary patients.

Level of consciousness at admission was not associated with outcome in this study, and even a dog that was determined to be comatose at initial examination recovered completely prior to discharge. Therefore, neurologic compromise at admission should not be used as a predictor of negative outcome. Hypothermia was associated with improved survival and neurologic outcome after cardiac arrest in 1 study and in another study, submersion time was a more important predictor of outcome than body temperature. Proposed theories for the higher survival rate in hypothermic humans have included reduced brain metabolism and oxygen demand. In the present study, no significant differences between survivors and nonsurvivors were found in rectal temperature, neurologic dysfunction, and survival. However, the number of cases enrolled in the study was limited, and it is possible that significant differences would have been found if a larger number of animals had been evaluated.

Most submersion took place during summer months, with many taking place in home swimming pools. This suggests that many submersion in the study population could have been prevented by implementing measures to restrict animals’ unsupervised exposure to water. A human study revealed that the incidence of drowning in children can be reduced by measures such as installation of a fence or barricade around home swimming pools.

All 3 cats in the present study were nonsurvivors. The importance of this finding in the small group of cats included is unknown; certainly, cats are rarely likely to swim on their own and perhaps are more likely to drown unobserved.

Limitations of this study include its retrospective nature and small sample size. Sample size likely influenced the fact that significant relationships were not found between outcome and any of the variables evaluated. However, respiratory failure appeared to result in most of the deaths. Potential prognostic indicators of outcome following submersion have been studied in humans. It has been proposed that a worse outcome is associated with increased duration of submersion, the presence of apnea, a Glasgow coma score ≤ 5, the need for cardiopulmonary resuscitation in the emergency room, and severe metabolic acidosis (pH ≤ 7.0). Overall, however, no study results have indicated a single prognostic indicator or combination of prognostic indicators that accurately predicts outcome in humans. Unfortunately, necropsy was infrequently performed in nonsurvivors in the present study. Histologic examination may be very useful in revealing and highlighting abnormalities in organ function or laboratory evaluation, such as defining tissue changes underlying high serum liver enzyme activity or cardiac arrhythmia. A larger study of submersion in animals is warranted, as is increased awareness of the syndrome in companion animals.
a. Cummings School of Veterinary Medicine, Tufts University, North Grafton, MA (n = 10); College of Veterinary Medicine, Michigan State University, East Lansing, MI (n = 10); College of Veterinary Medicine, University of Montreal, Quebec, Canada (n = 4); College of Veterinary Medicine, University of Minnesota, St. Paul, MN (n = 3); and the Royal Veterinary College, University of London, London, England (n = 1).

References