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Incidence, Severity and Prognosis Associated with Hyponatremia in Dogs and Cats

Y. Ueda, K. Hopper, and S.E. Epstein

Background: Hyponatremia is a common electrolyte abnormality in human patients and is associated with substantial morbidity and death. The incidence and importance of hyponatremia in dogs and cats has not been determined.

Hypothesis/Objectives: To describe the incidence of and prognosis associated with hyponatremia in dogs and cats at a university teaching hospital.

Animals: Of 16,691 dogs and 4,211 cats with measured blood or serum sodium concentration.

Methods: *Retrospective study*. Medical records of animals with a blood or serum sodium concentration measured during a 60-month period were reviewed to determine the severity of hyponatremia and its associated fatality rate. Cases with moderate (11–15 mmol/L below the reference range) or severe hyponatremia (≥16 mmol/L below the reference range) were further reviewed.

Results: Of 4,254 dogs (25.5%) and 2,081 cats (49.4%) were diagnosed with hyponatremia. Case fatality rates of dogs and cats with hyponatremia were 13.7% and 11.9%, respectively, compared to 4.4% and 4.5% with a normal blood or serum sodium concentration ($P < 0.0001$). The magnitude of hyponatremia was linearly associated with a higher case fatality rate ($P < 0.0001$). Hyponatremia was associated with a lower case fatality rate than hypernatremia in the same population. Among the animals with moderate or severe hyponatremia, 92.1% of dogs and 90.6% of cats presented with community-acquired hyponatremia, and 7.9% of dogs and 9.4% of cats developed hospital-acquired hyponatremia.

Conclusions and clinical importance: Hyponatremia was found commonly in this population and was associated with increased case fatality rate. Presence and severity of hyponatremia might be useful as a prognostic indicator.

Key words: Dysnatremia; Osmolality; Sodium; Water balance.

Hyponatremia is a common electrolyte abnormality in human patients and has been associated with substantial morbidity and death.[1–5] A large cohort study of >98,000 human patients identified an incidence of hyponatremia of 14.5% on initial concentration measured either at admission or during hospitalization.[6] Some studies of human patients reported hyponatremia to occur in approximately 30–40% of hospitalized patients.[7–10] In the emergency department, approximately 4.4–10% of human patients have hyponatremia,[1,11] whereas the incidence of hyponatremia on intensive care unit (ICU) admission is between 11.2 and 17.7% of human patients, depending on the population being assessed.[2,9,12–16] Studies of human patients also have shown that hyponatremia is associated with a high fatality rate, and it is an independent risk factor for poor prognosis.[2,5,15]

To date, no studies have reported the overall incidence, animal characteristics, or causes of hyponatremia in animals. The objective of this retrospective study was to evaluate the epidemiology of hyponatremia, primarily focusing on the overall incidence of this abnormality, concurrent underlying diseases, potential pathophysiologic factors contributing to development of hyponatremia and the associated morbidity and fatality rate in dogs and cats.

Abbreviations:

ADH	antidiuretic hormone
DKA	diabetic ketoacidosis
DM	diabetes mellitus
GI	gastrointestinal
ICU	intensive care unit

Materials and Methods

We used computerized medical records to identify all dogs and cats that had blood or serum sodium concentration measured on a blood gas determination or serum biochemistry profile during a 60-month period (January 1, 2008–December 31, 2012) at the University of California, Davis, William R. Pritchard, Veterinary Medical Teaching Hospital. This study included any dogs and cats that had a blood or serum sodium concentration measured at our institution during the specified time period.

Measurements

Blood or serum samples for sodium concentrations were measured using a point-of-care blood gas analyzer,[a] or 1 of 2 diagnostic laboratory biochemical analyzers.[b,c] At our institution, heparinized blood samples are measured for sodium as well as acid base parameters and other electrolytes immediately after sample collection using a point-of-care blood gas analyzer.[a] Alternatively, serum is submitted to the diagnostic laboratory for analysis within 12 h of sample collection. Using the point-of-care blood gas analyzer, the reference range for blood sodium concentration in dogs

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and cats were 145–153 mmol/L and 150–155 mmol/L, respectively. Using the diagnostic laboratory, the reference ranges for serum sodium concentration in dogs were 143–151 mmol/L before January 05, 2011 and 145–154 mmol/L thereafter. The reference ranges for serum sodium concentration in cats using the diagnostic laboratory was 151–158 mmol/L throughout the study period.

The medical records of all identified dogs and cats with at least 1 blood or serum sodium concentration measured were reviewed to determine the overall incidence and outcome of those animals with hyponatremia. Animals with a blood or serum sodium concentration less than the reference range were identified and categorized as borderline (≤5 mmol/L lower than the lowest reference concentration), mild (6–10 mmol/L lower than the lowest reference concentration), moderate (11–15 mmol/L lower than the lowest reference concentration), or severe (≥16 mmol/L lower than the lowest reference concentration) hyponatremia. The categorization used for severity of hyponatremia was chosen based on previous studies in human patients with some minor modifications.[2,17] Animals with s blood or serum sodium concentration higher than the reference range were categorized as hypernatremia in a similar manner and these results are presented in a companion article.[18] Animals could only be enrolled in the study once and only the first measured occurrence of hyponatremia identified in a hospital visit was included. The medical records of identified animals with moderate or severe hyponatremia were further reviewed to determine the primary disease processes, potential pathophysiologic factors contributing to hyponatremia, time of onset (community versus hospital-acquired), presence or absence of treatment given by referring veterinarians before presentation, hydration status, intravascular volume status and clinical signs noted when the animals developed hyponatremia. The primary disease process was determined by the primary clinicians and categorized based on major organ systems affected (respiratory, cardiovascular, neurological, musculoskeletal, gastrointestinal, hepatobiliary, urological, pancreatic, and reproductive systems). The specific diseases of neoplasia, sepsis, hypoadrenocorticism and diabetes mellitus (DM) were included separately either because they have multi-organ effects and could not be simply categorized to a single organ system or because they have specific relevance to hyponatremia. In addition, efforts were made to keep the categories used for primary disease processes consistent for both hypernatremia[18] and hyponatremia studies to facilitate comparison between the 2 groups of animals.

If hyponatremia was detected on the first blood sample in an admission period and no medical treatment was given by the referring veterinarians before presentation, it was categorized as community-acquired. If hyponatremia was not evident on admission blood sampling but was detected at a later point during hospitalization, it was categorized as hospital-acquired. In animals that had hyponatremia on admission but had received medical treatment by a referring veterinarian before presentation, the time of onset of hyponatremia was considered unknown. Hydration and intravascular volume status were based on the clinicians' description of the animals in the medical records on the day hyponatremia was first noted. The medical record also was searched for evidence of any predefined pathophysiologic factors considered to be possible contributors to the development of hyponatremia. Clinical signs noted when hyponatremia was detected were retrieved from history and physical examination findings when the animals developed hyponatremia.

Statistical Analysis

The proportion of animals that either died or were euthanized that had hyponatremia at least once, either on admission or during hospitalization, was compared to animals with a normal sodium concentration by Chi-square analysis using commercially available software.[d] Animals with hypernatremia were excluded from this analysis. Animals then were stratified into either severe, moderate, mild, borderline hyponatremia, or normal sodium concentration. The degree of sodium abnormality and outcome were compared by Chi-square analysis for trend. In post hoc analysis, case fatality rate for borderline hyponatremia was compared to the case fatality rate of animals with a normal sodium concentration by Chi-square analysis. $P < .05$ was considered significant.

Results

During the 60-month study period, 16,691 dogs and 4,211 cats were identified in which ≥1 blood samples were analyzed for blood or serum sodium concentration. Of these, 4,254 (25.5%) dogs and 2,081 (49.4%) cats were classified as having hyponatremia. The animal distributions in the categories of hyponatremia are listed in Table 1. The lowest sodium concentration measured was 102 mmol/L in dogs and 103 mmol/L in cats.

Dogs that had a normal sodium concentration measured during the study period had a case fatality rate of 4.4% (500/11,480) and cats had a case fatality rate of 4.5% (81/1,792). The overall case fatality rate of the animals with hyponatremia was 13.7% (581/4,254) in dogs and 11.9% (248/2,081) in cats. By comparison, case fatality rates with hypernatremia were 20.6% (197/957) in dogs and 28.1% (95/338) in cats from the same population.[18] There was a significant association of hyponatremia with nonsurvival in both dogs ($P < .0001$) and cats ($P < .0001$). The odds ratio (95% CI) of nonsurvival with all degrees of hyponatremia was 3.5 (3.0–3.9) in dogs and 2.9 (2.2–3.7) in cats. In addition, the magnitude of hyponatremia was linearly associated with higher case fatality rate in both dogs and cats ($P < .0001$; Fig. 1). In both dogs and cats, case fatality rates for borderline hyponatremia were significantly higher than in those with normal blood or serum sodium concentration ($P < .0001$).

Of the 217 dogs with moderate or severe hyponatremia, 70% (152/217) of dogs could be classified according to the timing of development of hyponatremia. Of these animals, 92.1% (140/152) of dogs presented with

Table 1. Incidence of abnormal blood or serum sodium concentration in dogs and cats at a veterinary medical teaching hospital.

	Dogs *N* (%)	Cats *N* (%)
Total	16,691	4,211
Normal Sodium	11,480 (68.8)	1,792 (42.6)
All Hyponatremia	4,254 (25.5)	2,081 (49.4)
Severe	79 (0.5)	32 (0.8)
Moderate	138 (0.8)	60 (1.4)
Mild	455 (2.7)	246 (5.8)
Borderline	3,582 (21.5)	1,743 (41.4)
All Hypernatremia	957 (5.7)	338 (8)

Borderline hyponatremia, ≤5 mmol/L lower than the lowest reference concentration; mild hyponatremia, 6–10 mmol/L lower than the lowest reference concentration; moderate hyponatremia, 11–15 mmol/L lower than the lowest reference concentration; severe hyponatremia, ≥16 mmol/L lower than the lowest reference concentration.

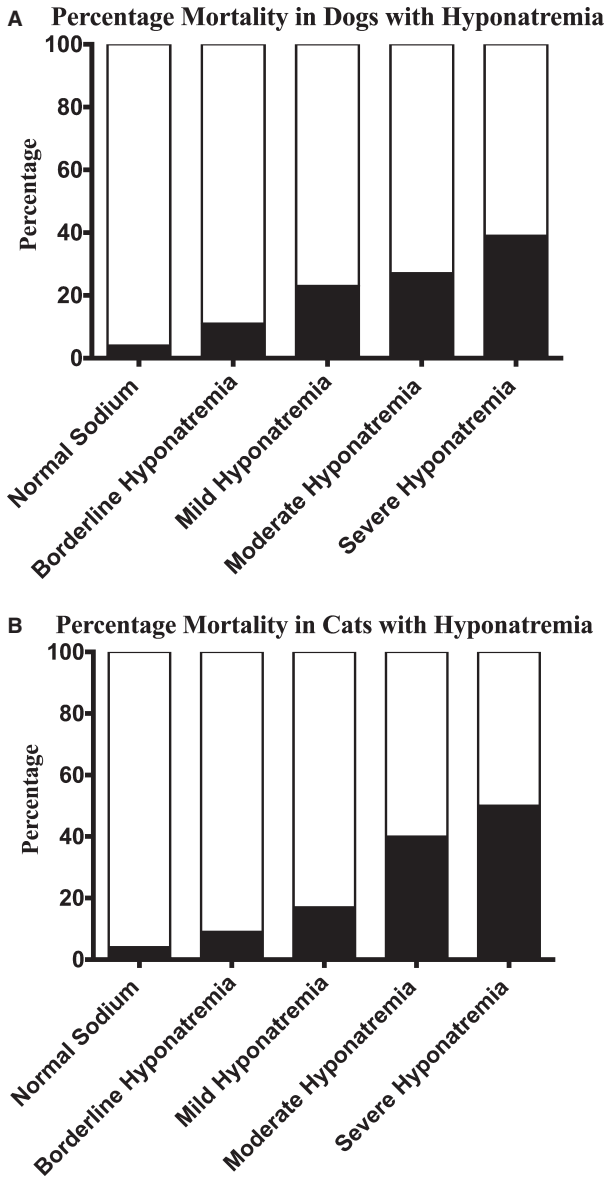

Fig 1. Percent death among various degrees of hyponatremia in dogs (**A**) and cats (**B**). There is a linear association of increasing case fatality rate with greater hyponatremia $P < 0.0001$. Hyponatremia was categorized as borderline (≤5 mmol/L lower than the lowest reference concentration), mild (6–10 mmol/L lower than the lowest reference concentration), moderate (11–15 mmol/L lower than the lowest reference concentration), or severe (≥16 mmol/L lower than the lowest reference concentration). The white area of each column represents the percentage of survivors and the black area represents the percentage of death.

community-acquired hyponatremia whereas only 7.9% (12/152) of dogs developed hospital-acquired hyponatremia. Thirty percent of dogs (65/217) had received medical treatment by a referring veterinarian before presentation to our hospital, and the time of onset of hyponatremia was considered unknown. In cats with moderate or severe hyponatremia, 58% (53/92) could be classified according to the timing of development of hyponatremia. Of these, 90.6% (48/53) presented with community-acquired hyponatremia and 9.4% (5/53) developed hospital-acquired hyponatremia. Forty-two percent of cats (39/92) had received medical treatment by a referring veterinarian before presentation to our hospital, and the time of onset of hyponatremia was considered unknown. Among animals with moderate or severe hyponatremia, 29% (65/217) of dogs and 42.3% (39/92) of cats received medical treatment by the referring veterinarians before presentation and thus were not included in the cases of community and hospital-acquired hyponatremia.

The primary disease processes of the animals with moderate or severe hyponatremia are shown in Table 2. The most frequent disease processes identified in dogs were gastrointestinal (GI; 38/217, 17.5%), urological (38/217, 17.5%), and cardiovascular (30/217, 13.8%). In cats with moderate or severe hyponatremia, the most frequent disease processes were urological (28/92, 30.4%), hepatobiliary (17/92, 18.5%), and cardiovascular (13/92, 14.1%). In both dogs and cats, many animals had >1 concurrent disease.

Pathophysiologic factors potentially contributing to the development of hyponatremia are shown in Table 3. In dogs, GI fluid loss caused by vomiting and diarrhea were the most common factors identified (121/217, 55.8%), followed by third space fluid loss (42/217, 21.7%), and fluid shift from intracellular to extracellular spaces because of moderate to severe hyperglycemia (29/217, 13.4%). In cats, the most common pathophysiologic factors potentially contributing to the development of hyponatremia were urological diseases (32/92, 34.8%), followed by GI fluid loss caused by vomiting and diarrhea (26/92, 28.3%), and third space fluid loss (24/92, 26.2%). The majority of animals had >1 pathophysiologic factor potentially leading to hyponatremia.

Signs of dehydration were noted in the medical records in 41.5% (90/217) of dogs and 57.6% (53/92) of cats at the time moderate or severe hyponatremia was identified, whereas 1.8% (4/217) of dogs and 6.5% (3/92) of cats were noted to have signs of overhydration. Of dogs with moderate or severe hyponatremia, 30.4% (66/217) showed clinical signs of hypovolemia, 60.4% (131/217) were considered euvolemic, and 8.8% (19/217) had signs of hypervolemia. In cats, 25% (23/92) showed the signs of hypovolemia, 57.6% (53/92) were considered euvolemic, and 16.3% (15/92) had signs of hypervolemia.

The clinical signs of dogs at the time moderate or severe hyponatremia were identified included obtundation (103/217, 47.5%), lethargy (96/217, 44.2%), and vomiting(95/217, 43.8%). Cats with moderate or severe hyponatremia showed lethargy (58/92, 63%), obtundation (45/92, 48.9%), and vomiting (26/92, 28.3%) at the time of diagnosis (Table 4).

Discussion

Hyponatremia was a common abnormality in dogs and cats in which a blood or serum sodium concentration was evaluated at the Veterinary Medical Teaching Hospital. The overall incidence was 25.5% and 49.4%

Table 2. Primary disease processes of dogs and cats identified with moderate or severe hyponatremia. Note, individual animals may have >1 condition.

	Dogs with Hyponatremia *N* (%)			Cats with Hyponatremia *N* (%)		
Primary disease processes	Moderate	Severe	Total	Moderate	Severe	Total
Total	138	79	217	60	32	92
Gastrointestinal	25 (18.1)	13 (16.5)	38 (17.5)	4 (6.67)	4 (12.5)	8 (8.7)
Urological	26 (18.8)	12 (15.2)	38 (17.5)	18 (30)	10 (31.3)	28 (30.4)
Cardiovascular	19 (13.8)	11 (13.9)	30 (13.8)	10 (16.7)	3 (9.38)	13 (14.1)
Neoplasia	20 (14.5)	9 (11.4)	29 (13.4)	9 (15)	3 (9.4)	12 (13)
DM/DKA	16 (11.6)	11 (13.9)	27 (12.4)	2 (3.3)	1 (3.1)	3 (3.3)
Respiratory	18 (13)	7 (8.9)	25 (11.5)	2 (3.3)	1 (3.1)	3 (3.3)
Hepatobiliary	17 (12.3)	6 (7.6)	23 (10.6)	11 (18.3)	6 (18.8)	17 (18.5)
Pancreatic	13 (9.4)	9 (11.4)	22 (10.1)	2 (3.3)	1 (3.1)	3 (3.3)
Hypoadrenocorticism	9 (6.5)	13 (16.5)	22 (10.1)	0	0	0
Neurological	13 (9.4)	4 (5.1)	17 (7.8)	1 (1.7)	2 (6.3)	3 (3.3)
Sepsis	5 (3.6)	10 (12.7)	15 (6.9)	3 (5)	3 (9.4)	6 (6.5)
Reproductive	6 (4.4)	6 (7.6)	12 (5.5)	1 (1.7)	0	1 (1.1)
Musculoskeletal	2 (1.5)	3 (3.8)	5 (2.3)	0	1 (3.1)	1 (1.1)

DM (diabetes mellitus), DKA (diabetic ketoacidosis).

Moderate hyponatremia, 11–15 mmol/L lower than the lowest reference concentration; severe hyponatremia, ≥16 mmol/L lower than the lowest reference concentration.

Table 3. Potential pathophysiologic factors that might have contributed to development of hyponatremia in dogs and cats identified with moderate or severe hyponatremia. Note that individual animals may have >1 condition.

	Dogs with Hyponatremia *N* (%)			Cats with Hyponatremia *N* (%)		
Pathophysiologic factors	Moderate	Severe	Total	Moderate	Severe	Total
Total	138	79	217	60	32	92
GI loss	74 (53.6)	47 (59.5)	121 (55.8)	16 (26.7)	10 (31.3)	26 (28.3)
Third space loss	27 (19.6)	16 (20.3)	43 (19.8)	13 (21.7)	11 (34.4)	24 (26.1)
Hyperglycemia	16 (11.6)	13 (16.5)	29 (13.4)	2 (3.3)	2 (6.3)	4 (4.4)
Hypoadrenocorticism	9 (6.5)	12 (15.2)	21 (9.7)	0	0	0
Advanced renal failure	13 (9.4)	7 (8.9)	20 (9.2)	22 (36.6)	10 (31.3)	32 (34.8)
Congestive heart failure	5 (3.6)	7 (8.9)	12 (5.5)	9 (15)	3 (9.4)	12 (13)
Edema	8 (5.8)	2 (2.5)	10 (4.6)	2 (3.3)	1 (3.1)	3 (3.3)
Mannitol infusion	8 (5.8)	0	8 (3.7)	0	0	0
Severe liver disease	3 (2.2)	3 (3.8)	6 (2.8)	6 (10)	4 (12.5)	10 (10.9)
SIADH	4 (2.9)	0	4 (1.8)	0	1 (3.1)	1 (1.1)
DDAVP administration	0	2 (2.5)	2 (0.9)	0	0	0
Cutaneous loss	2 (1.5)	0	2 (0.9)	0	0	0
Unknown	6 (4.4)	0	6 (2.8)	10 (16.7)	5 (15.6)	15 (16.3)

DM (diabetes mellitus), DKA (diabetic ketoacidosis), SIADH (syndrome of inappropriate antidiuretic hormone secretion), DDAVP (desmopressin acetate).

Moderate hyponatremia, 11–15 mmol/L lower than the lowest reference concentration; severe hyponatremia, ≥16 mmol/L lower than the lowest reference concentration.

in dogs and cats, respectively. Hyponatremia was 4.5 times more frequent in dogs and 6.2 times more frequent in cats than hypernatremia in the same population.[18] The incidence of hyponatremia in this study was similar to that reported in hospitalized human patients.[7–10] Of the animals in this study in which the time of onset of hyponatremia could be determined, the majority were considered to have community-acquired hyponatremia. In contrast, the incidence of community-acquired hyponatremia in human patients is lower, in the range of 4–17.7% depending on the population being assessed.[1,2,6,9,11–16] Dogs and cats might be hospitalized later in the course of their disease or have different underlying diseases causing hyponatremia that might explain why hyponatremia is more common on presentation than arising during hospitalization. In human patients, hyponatremia often is the consequence of chronic organ dysfunction such as heart failure or liver cirrhosis. Also, it often is associated with thiazide use and the syndrome of inappropriate antidiuretic hormone secretion.[19] The time of onset of hyponatremia for 30% of dogs and 42% of cats with moderate or

Table 4. Clinical signs present in dogs and cats with moderate or severe hyponatremia. Note that individual animals may have >1 clinical sign.

	Dogs with Hyponatremia *N* (%)			Cats with Hyponatremia *N* (%)		
Clinical Signs	Moderate	Severe	Total	Moderate	Severe	Total
Total	138	79	217	60	32	92
Obtundation	60 (43.5)	43 (54.4)	103 (47.5)	30 (50)	15 (46.9)	45 (48.9)
Lethargy	62 (44.9)	34 (43)	96 (44.2)	36 (60)	22 (68.8)	58 (63)
Vomiting	72 (52.1)	23 (29.1)	95 (43.8)	13 (21.7)	13 (40.6)	26 (28.3)
Weakness	19 (13.8)	18 (22.8)	37 (17.1)	14 (23.3)	3 (9.4)	17 (18.5)
None	19 (13.8	11 (13.9)	30 (13.8)	7 (11.7)	3 (9.4)	10 (10.9)
Seizure	7 (5.1)	8 (10.1)	15 (6.9)	0	3 (9.4)	3 (3.3)
Stuporous	7 (5.1)	7 (8.9)	14 (6.5)	3 (5)	2 (6.3)	5 (5.4)
Ataxia	4 (2.9)	4 (5.1)	8 (3.7)	5 (8.3)	3 (9.4)	8 (8.7)
Tremor	3 (2.2)	4 (5.1)	7 (3.2)	1 (1.7)	1 (3.1)	2 (2.2)
Comatose	4 (2.9)	1 (1.3)	5 (2.3)	0	1 (3.1)	1 (1.1)

Moderate hyponatremia, 11–15 mmol/L lower than the lowest reference concentration; severe hyponatremia, ≥16 mmol/L lower than the lowest reference concentration.

severe hyponatremia in this study could not be determined and this observation limited the ability to accurately determine the incidence of community-acquired versus hospital-acquired hyponatremia.

In our study, the overall case fatality rate of dogs and cats with hyponatremia was significantly higher than that of animals with normal blood or serum sodium concentration. In addition, increasing severity of hyponatremia was linearly associated with higher case fatality rate and even borderline hyponatremia (sodium concentration ≤5 mmol/L below the lower limit of the reference range) was associated with an increased case fatality rate. Similar findings have been reported in human patients at hospital admission, in patients hospitalized in the general ward as well as in ICU patients.[2,6,12,14,20,21] However, the mechanism by which hyponatremia contributes to death currently is unknown. It has not been established if hyponatremia is purely a marker of underlying disease, if it has direct harmful effects or if it is because of a combination of these effects. Interestingly, a recent study found that correction of hyponatremia was associated with improved survival in critically ill human patients.[22] This finding might imply that hyponatremia directly affects animal death.

Moderate or severe hyponatremia in this study population was associated with a variety of disease processes and potential pathophysiologic factors. Volume depletion was a common finding in dog and cats with moderate or severe hyponatremia in this study. It can be manifested as hypovolemia caused by volume depletion in the intravascular space, dehydration caused by volume depletion in the interstitial space or some combination of these factors. In this study, 30.4% of dogs and 28% of cats with moderate or severe hyponatremia were considered hypovolemic and 41.5% of dogs and 57.6% of cats with moderate or severe hyponatremia had signs of dehydration at the time hyponatremia was first identified. Common causes of volume depletion included vomiting and diarrhea. Fifty-six percent of dogs and 27% of cats in this study had episodes of vomiting, diarrhea or both. Both nausea and volume depletion are strong nonosmotic stimuli for antidiuretic hormone (ADH) release, which stimulates water retention by the kidneys, potentially leading to development of hyponatremia.

Third space fluid loss was identified in 19.8% of dogs and 26.1% of cats with moderate or severe hyponatremia in this study and is another common cause of volume depletion. Hyponatremia associated with peritoneal and pleural effusion has been reported in previous studies in dogs and cats.[23–25] Hyponatremia can occur in these animals without repeated drainage of fluid from the third spaces.[23]

Urological disease was found to be a common clinical diagnosis associated with moderate or severe hyponatremia in both dogs (17.5%) and cats (30.4%). Progressive kidney failure impairs urinary dilution, as manifested by an inability to maximally lower urine osmolality after a water load.[19,26] In this study, the severity of urological disease was not assessed and thus it is unknown if these animals developed hyponatremia as a consequence of oliguric or anuric kidney failure or as a result of other mechanisms such as vomiting, which is a common clinical sign associated with kidney disease.

Fourteen percent of both dogs and cats with moderate or severe hyponatremia in this study were diagnosed with cardiovascular diseases. Among these animals, 40% of dogs and 92.3% of cats showed signs of congestive heart failure. Congestive heart failure is associated with decreased effective circulating volume which might lead to impaired free water excretion as a result of decreased glomerular filtration rate and nonosmotic stimulation of ADH release, leading to hyponatremia. Hyponatremia in the congestive heart failure in the human patient has been associated with a worse prognosis in both human patients and animals.[27–29]

Hepatobiliary disease was the second most common primary disease process in cats (18.5%) with moderate or severe hyponatremia in this study. In severe liver disease, arteriovenous shunting, splanchnic venous

pooling, ascites caused by portal hypertension, and decreased oncotic pressure caused by hypoalbuminemia all might lead to decreased effective circulating volume resulting in nonosmotic stimulation of ADH release.[26,30–32] Also, animals with hepatobiliary disease often show GI signs, such as vomiting and diarrhea, which might result in fluid loss and subsequent nonosmotic stimulation of ADH release.

Hypoadrenocorticism and severe hyperglycemia arising from DM or diabetic ketoacidosis (DKA) have been anecdotally believed to be common causes of hyponatremia in dogs. However, only 10.1% dogs with moderate or severe hyponatremia were primarily diagnosed with hypoadrenocorticism and 12.4% had DM or DKA. There are several possible explanations for this finding. First, these diseases might cause mild hyponatremia more often than moderate or severe hyponatremia. Second, the incidence of these diseases might not be as common as other diseases diagnosed at the Veterinary Medical Teaching Hospital because it is a tertiary referral center. Finally, hypoadrenocorticism, DM and DKA might truly be infrequent causes of hyponatremia in dogs and cats.

The major clinical concern of acute hyponatremia is encephalopathy because of cerebral edema. Initial clinical signs reported in human patients are nonspecific and include nausea and lethargy.[1,19,33] Advanced clinical signs include obtundation, decreased reflexes, weakness, seizures, and coma followed by death.[19,26] Chronic hyponatremia often is asymptomatic because of osmotic adaptation. In this study, the common clinical signs evident in animals with moderate or severe hyponatremia were obtundation (47.5% in dogs, 48.9% in cats), lethargy (44.2% in dogs, 63% in cats), vomiting (43.8% in dogs, 28.3% in cats), and weakness (17.1% in dogs, 18.5% in cats). Some animals also showed more severe mentation changes, ataxia, tremors, and seizures. Given the retrospective nature of this study, clinical signs caused by hyponatremia cannot be differentiated from clinical signs caused by other underlying diseases.

Our study has limitations inherent to a retrospective study. Because of limited information with regard to timing of measuring sodium concentration in association with therapeutic intervention before and after presentation, it is difficult to determine the direct and indirect effects of medical therapies. Possible causes and clinical signs of hyponatremia were identified in this study, but there was no way to confirm any relationship between these findings and the occurrence of hyponatremia. The true incidence of hyponatremia in dogs and cats cannot be determined by this study because only animals that had a blood or serum sodium concentration measured were included. A prospective study in which all animals presenting to a veterinary facility would have blood or serum sodium concentration measured on admission and followed during the hospital stay would be ideal.

In conclusion, hyponatremia was a common abnormality in a large group of hospitalized dogs and cats at a veterinary medical teaching hospital, and the overall incidence of hyponatremia was higher in cats than in dogs. The majority of animals with moderate or severe hyponatremia were diagnosed at presentation, whereas only a small number of animals developed moderate or severe hyponatremia during their hospitalization. The overall case fatality rate of animals with hyponatremia was significantly higher than that of animals that had a normal sodium concentration but less than that of animals with hypernatremia.[18] A significant linear association of higher case fatality rate with more severe hyponatremia in both dogs and cats was found, with even borderline hyponatremia associated with an increased case fatality rate. Future prospective studies to better determine the causes of hyponatremia in animals are needed. Ongoing investigations in animals and human patients might determine if the prognostic relevance of hyponatremia is a marker of disease severity or a direct cause of morbidity.

Footnotes

[a] ABL 705, Radiometer Medical A/S, Copenhagen, Denmark
[b] Chemistry analyzer, Hitachi 917, Roche Diagnostics, Indianapolis, IN
[c] Chemistry analyzer, Hitachi c501, Roche Diagnostics, Indianapolis, IN
[d] GraphPad Prism 6.0, Graph Pad Software, La Jolla, CA

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Conflict of Interest Declaration: Authors disclose no conflict of interest.

Off-label Antimicrobial Declaration: Authors declare no off-label use of antimicrobials.

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