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Incidence of hypochloremic metabolic alkalosis in dogs and cats with and without nasogastric tubes over a period of up to 36 hours in the intensive care unit

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Abstract

Objective – To evaluate the incidence of hypochloremic metabolic alkalosis (HCMA) in dogs and cats in the ICU that had intermittent nasogastric tube (NGT) aspiration for up to 36 hours.
Design – Prospective cohort study (December 2013 to October 2014).
Setting – Privately owned emergency and referral teaching hospital.
Animals – Forty-nine client-owned dogs and 16 client-owned cats.
Interventions – Patients wherein NGT placement was recommended and client consent was obtained were included in the interventional group. Those with an NGT placed (NGT group) had the NGT aspirated every 4 hours. Patients for whom placement of a NGT was declined by the owner served as a reference group (NoNGT). Venous blood gas and electrolyte values were obtained every 12 hours.
Measurements and Main Results – Thirty-five dogs and cats had an NGT placed. Thirty dogs and cats did not have an NGT placed. The serum venous blood gas and electrolyte changes were compared over time within the NGT group and between the NGT and NoNGT groups. No cases developed HCMA. In the NGT group, blood pH increased over time. There was no significant difference between the NGT and the NoNGT group in the average value of pH, HCO_3^-, base excess, chloride, or corrected chloride. Serum venous blood gas, chloride, and corrected chloride changes were not associated with the volumes of gastric fluid aspirated over time.
Conclusions – In this small population of dogs and cats, intermittent NGT aspiration was not associated with the development of HCMA over a period of up to 36 hours after NGT placement.

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Keywords: acid base balance, canine, chloride, feeding tube, feline, prokinetic

Abbreviations

BE	base excess
CI	confidence interval
CoCl	corrected chloride
HCMA	hypochloremic metabolic alkalosis
NGT	nasogastric tube
NoNGT	no NGT placement
RER	resting energy requirement

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Introduction

Severe metabolic alkalosis in critically ill people can be associated with life-threatening problems, including arrhythmias,[1] myoclonus,[2] and transient hypoventilation,[3–6] as well as disorientation, stupor, and coma.[7] In dogs, weakness can occur following the development of a metabolic alkalosis.[8] Metabolic alkalosis frequently occurs in conjunction with a hypochloremia.[9] In people, a severe metabolic alkalosis (pH > 7.60) and a severe hypochloremia (chloride < 98 mmol/L [98 mEq/L]) have been independently associated with an increase in mortality.[10,11]

Hypochloremic metabolic alkalosis (HCMA) has been cited in several veterinary textbooks and practice manuals as a potential complication of repeated aspiration of gastric fluid by a nasogastric tube (NGT) in dogs and cats.[9,12–21] NGT placement is a common procedure performed in veterinary patients, and is indicated when a patient is vomiting, not eating voluntarily, or has gastric distension. It provides a means to supplement enteral nutrition, administer oral medication, decompress a fluid or gas dilated stomach, and to quantify gastric residual fluid volume. In people, reinfusing aspirated gastric fluid has been recommended to avoid the development of HCMA.[22] Additional factors that can influence the development of HCMA include intravenous fluid choice (use of 0.9% sodium chloride [NaCl]), use of prokinetic drugs, potassium chloride (KCl), furosemide or bicarbonate, and adrenal or kidney disease.

The incidence of HCMA secondary to intermittent gastric fluid aspiration in the dog and cat has not been documented. The primary objective of this study was to prospectively examine the incidence of HCMA in dogs and cats with intermittent removal of gastric contents by aspiration through indwelling NGTs. The null hypothesis is that the intermittent aspiration of gastric fluid through an indwelling NGT is not associated with HCMA in the dog and cat during the first 36 hours after NGT placement. Additional objectives were to: (1) compare changes in serum venous blood gas, chloride, and corrected chloride (CoCl) between patients with and without NGTs, and (2) examine the impact of volume of gastric fluid suctioned, use of prokinetic agents, and KCl supplementation on serum venous blood gas, chloride, and CoCl values in patients with NGTs.

Materials and Methods

Criteria for selection of cases

The study protocol was approved by the Institutional Animal Use and Care Committee. Dogs and cats that were evaluated and hospitalized for vomiting or anorexia at a private emergency and referral hospital from December 2013 to October 2014 were eligible for the study. Twenty-eight patients per group were needed to detect a difference of $\geq$0.3 in the HCMA incidence in the NGT group when compared to an expected incidence of $<$0.001 in the NoNGT group with 95% confidence and 80% power.[23]

Cases selected to participate in the study were those in which placement of an NGT was recommended for the purpose of removing gastric fluid or air or providing enteral nutrition because they were vomiting, anorexic, or had gastric stasis, and client consented to participate in the study. Those patients for whom the client declined placement of a NGT served as the reference group (NoNGT group). Written consent was obtained from all owners to use data collected on their dog or cat.

Exclusion criteria included the presence of baseline alkalemia, baseline hypochloremia, or current treatment with H_2-receptor antagonists, proton pump inhibitors, diuretics, or bicarbonate. Animals that were hospitalized for less than or equal to 12 hours after NGT placement were also excluded. Patient care was the responsibility of the primary clinician assigned to the case at that time.

NGT and nutrition

Placement of NGTs[a,b] was standardized using a technique previously described.[24] An initial serum venous blood gas and electrolyte panel were obtained within 15 minutes of placement of the NGT to ensure that no exclusion criteria existed prior to being included in the study. The NGT was aspirated every 4 hours and residual volume was recorded and discarded. Following aspiration, the NGT was flushed with a fixed volume of tap water (equivalent to the volume the NGT holds) in order to maintain tube patency.

The resting energy requirement (RER) was estimated using the following formula: $\text{RER} = 30 \times \text{body weight (kg)} + 70$. When nutrition was provided via the NGT, it was initiated within 12 hours of placement. A liquid nutrition diet[c] was delivered via the NGT at 1/4 RER for the first 6 hours, and if no vomiting or regurgitation occurred, the RER was increased by 25% every 6 to 8 hours until full RER was being administered. If the aspirated volume exceeded the volume of liquid nutrition infused, the volume infused was decreased to the previous volume prescribed. Animals in the NoNGT group were allowed access to food at the clinician's discretion.

Sampling

Blood samples were collected at baseline, and then evaluated every 12 hours, for up to 36 hours. A minimum of 2 samples (which included the baseline sample) were obtained. Venous blood samples were collected in lithium-heparin tubes and immediately evaluated.

Blood pH, P_vCO_2, base excess (BE), sodium, and chloride were measured with a blood gas analyzer.[d] Bicarbonate (HCO_3^-) was calculated by the blood gas analyzer using the Henderson–Hasselbalch equation. To correct for changes in chloride due to water imbalances, the following formula was used: CoCl = measured chloride $\times$ (normal sodium/measured sodium). Based on reference values established for normal dogs and cats for this analyzer,[d] a normal sodium value was considered to be 148 mmol/L (148 mEq/L) in dogs (reference interval, 140–151 mmol/L [140–151 mEq/L]) and 152 mmol/L

(152 mEq/L) in cats (reference interval, 148–163 mmol/L [148–163 mEq/L]). The normal chloride reference interval on the analyzer is 106–127 mmol/L (106–127 mEq/L) in dogs and 111–128 mmol/L (111–128 mEq/L) in cats. HCMA was diagnosed if all the following criteria were met:

i. pH > 7.46 in dogs; pH > 7.43 in cats.[d]
ii. HCO_3^- > 28 mmol/L (28 mEq/L) in dogs; HCO_3^- > 27 mmol/L (27 mEq/L) in cats.[d]
iii. CoCl < 106 mmol/L (106 mEq/L) in dogs; CoCl < 111 mmol/L (111 mEq/L) in cats.[d]
iv. BE > 5.0 mmol/L (5.0 mEq/L) in dogs; BE > 2.0 mmol/L (2.0 mEq/L) in cats.[d]

Data evaluation

Signalment, presenting clinical signs, acute disease processes, venous blood gas and electrolyte values, and volume of fluid aspirated from the NGT over a 12-hour period were recorded. The use, type, and dosage of adjunctive therapy were also recorded. The following outcomes were evaluated: (1) the occurrence of HCMA in the NGT group and NoNGT group, (2) changes in serum venous blood gas, chloride, and CoCl values from baseline to 12, 24, and 36 hours post-NGT placement, (3) whether changes in serum venous blood gas, chloride, and CoCl were associated with volumes of gastric fluid aspirated, the addition of prokinetic medication, or KCl supplementation, and (4) whether the use of prokinetic agents influenced the amount of gastric fluid aspirated.

Statistical analysis

The age, body condition score, and weight of both dogs and cats in the study population were summarized using descriptive statistics for patients with and without NGTs. Serum venous blood gas and electrolytes were also summarized across all time points for each group. The occurrence of HCMA was reported with 95% confidence intervals (CI) for patients with and without NGT placement.

Changes over time in each measured serum venous blood gas and electrolyte value of interest for patients in the NGT group were examined using generalized estimating equations with a normal distribution and autoregressive correlation structure to account for the repeated measures design.[e] Differences were examined between the initial blood sample and those available at 12, 24, and 36 hours after NGT placement. Species, age, and gender were evaluated to determine if they were potential confounders by examining the impact of adding or removing each of them from the model on the regression coefficients of interest. Species and age were subsequently included in all models and average differences in serum venous blood gas and electrolyte values associated with species and age were reported.

In the second step, generalized estimating equations as described above were used to evaluate the difference in individual serum venous blood gas and electrolyte values as well as changes over time between the NGT group compared to the NoNGT group. We first examined a model for each outcome comparing average values for treated and not treated accounting for time, species, and age. We then examined a model that also included an interaction between treatment and time to look at the difference in changes over time between the groups.

The potential impact of the amount of fluid aspirated on each measured serum venous blood gas and electrolyte value was then examined for the NGT group by including the amount of fluid aspirated in the above model. In the next step, an interaction term was added between collection time and amount of fluid aspirated to identify any changes in the effect of the amount of fluid aspirated over time. Similar models were subsequently examined to determine the impact of prokinetic medication and KCl supplementation use on average serum venous blood gas and electrolyte values, and changes over time.

Model residuals were examined for assumptions of normality, homogeneity of variance, and extreme outliers. A P-value < 0.05 was considered statistically significant.

Results

NGT group

Forty-nine client-owned dogs and 16 client-owned cats were recruited for the study; 23 dogs and 12 cats had an NGT placed. Tables 1 and 2 list the demographics, age, body weight, and adjunctive therapy of the NGT group for dogs and cats.

Table 3 lists the reasons for NGT placement in the NGT group. The final diagnosis for patients in the NGT group included: pancreatitis ($n = 2$ dogs, 2 cats), postoperative enterotomy for foreign body removal ($n = 4$ dogs), hepatopathy ($n = 1$ dog, 2 cats), gastric dilatation volvulus ($n = 2$ dogs), atypical hypoadrenocorticism ($n = 1$ dog), bilateral pyothorax ($n = 1$ dog), blastomycosis ($n = 1$ dog), cholecystectomy ($n = 1$ dog), diarrhea ($n = 1$ dog), gastric dilatation ($n = 1$ dog), hyperthyroidism ($n = 1$ cat), multiple dental extractions ($n = 1$ dog), and pyometra ($n = 1$ dog). Some cases had multiple disease processes.

In the NGT group, all patients received an intravenous balanced isotonic crystalloid. Plasmalyte-A[f] was administered to 34/35 (97%) patients and 1/35 (3%) patients received lactated Ringer's solution. Six out of 35 (17%) patients received hydroxyethyl starch.[g] Two out of 35

Table 1: Demographics, age, body weight, and adjunctive therapy for dogs in the nasogastric group (NGT) and no nasogastric tube (NoNGT) group

	NGT $n = 23$	NoNGT $n = 26$
Male/male neutered	12/9	12/8
Female/female neutered	11/11	14/14
Age in years (mean ± SD)	7.0 ± 3.3	5.6 ± 3.8
Weight in kg (mean ± SD)	22.3 ± 16	21 ± 12
Plasmalyte-A	22 (96%)	26 (100%)
Lactated Ringer's solution	1 (4.3%)	0
Vetstarch	6 (26%)	3 (11.5%)
Dextrose	2 (8.7%)	1 (3.8%)
Dopamine CRI in 0.9% NaCl	2 (8.7%)	0
Insulin CRI in 0.9% NaCl	0	1 (3.8%)
Prokinetic therapy	19 (83%)	8 (31%)
KCl supplementation	4 (17%)	1 (3.8%)

CRI, constant rate infusion; KCl, potassium chloride; NaCl, sodium chloride; SD, standard deviation.

Table 2: Demographics, age, body weight, and adjunctive therapy for cats in the nasogastric group (NGT) and no nasogastric tube (NoNGT) group

	NGT $n = 12$	NoNGT $n = 4$
Male/male neutered	8/8	1/1
Female/female neutered	4/4	3/3
Age in years (mean ± SD)	7.8 ± 4.6	12 ± 7.8
Weight in kg (mean ± SD)	4.6 ± 1.5	3.6 ± 0.92
Plasmalyte-A	12 (100%)	4 (100%)
Lactated Ringer's solution	0	0
Vetstarch	0	0
Dextrose	0	0
Dopamine CRI in 0.9% NaCl	0	0
Insulin CRI in 0.9% NaCl	0	1 (25%)
Prokinetic therapy	11 (91.7%)	1 (25%)
KCl supplementation	2 (16.7%)	2 (50%)

CRI, constant rate infusion; KCl, potassium chloride; SD, standard deviation.

(6%) patients received supplemental (2.5–5%) dextrose[h] and 2/35 (6%) patients were treated with a dopamine[i] constant rate infusion using 0.9% NaCl solution.[j]

No NGT group

Of the 65 patients in the study, 26/49 dogs and 4/16 cats did not have an NGT placed. Tables 1 and 2 list the demographics, age, body weight, and adjunctive therapy of the NoNGT group for dogs and cats. Table 3 lists the reasons why NGT placement was indicated in the NoNGT group. Additional problems identified in the NoNGT group included: hematochezia ($n = 4$), pyelonephritis ($n = 2$), cholecystectomy ($n = 1$), cystotomy ($n = 1$), diabetes mellitus ($n = 1$), enterotomy for a foreign body ($n = 1$), gastric foreign body ($n = 1$), hepatopathy ($n = 1$), nicotine ingestion ($n = 1$), oropharyngeal swelling ($n = 1$), polyarthropathy ($n = 1$), and urinary tract infection ($n = 1$). All patients received an intravenous balanced isotonic crystalloid (Plasmalyte-A[f]) and 3 patients also received hydroxyethyl starch.[g]

Incidence of HCMA and venous blood gas and chloride concentrations

There was no development of HCMA in either the NGT group (incidence 0.0% (0/35); 95% CI 0.0% to 10.0%) or the NoNGT group (incidence 0.0% (0/30); 95% CI 0.0% to 11.6%) in the 36-hour observation window of all patients. The serum venous blood gas and electrolyte values for the NGT group and the NoNGT group at each time point during the 36-hour observation window are listed in Tables 4 and 5. After accounting for differences in values across sample times from 0 to 36 hours and differences associated with the age of each patient, the pH ($P = 0.022$) was higher in dogs than cats. The P_vCO_2 ($P = 0.002$) and CoCl ($P = 0.004$) were higher in cats compared to dogs. After accounting for the differences

Table 3: Patient grouping based on reasons for nasogastric tube placement and average volume gastric fluid aspirated (mean and standard deviation)

	Vomiting	Nutritional support	Decompression	Vomiting & nutritional support	Vomiting & decompression
NGT group					
Dogs ($n = 23$)	3	4	3	12	1
Mean volume of fluid aspirated (mL/kg/h ± SD)	0.16 ± 0.18	1.59 ± 1.96	0.75 ± 0.65	0.90 ± 1.19	0.57 NA
Cats ($n = 12$)	1	5	0	6	0
Mean volume of fluid aspirated (mL/kg/h ± SD)	0.01 NA	3.03 ± 4.28	NA	1.15 ± 1.73	NA
NoNGT group					
Dogs ($n = 26$)	12	3	0	11	0
Cats ($n = 4$)	0	1	0	3	0

NA, not applicable; NGT, nasogastric tube; NoNGT, no nasogastric tube placement; SD, standard deviation.

Table 4: Serum venous blood gas values and chloride concentrations (mean and standard deviation) in dogs and cats following nasogastric tube (NGT) placement

	Reference interval*	0 hours $n = 23$ dogs, 12 cats	12 hours $n = 23$ dogs, 12 cats	24 hours $n = 19$ dogs, 12 cats	36 hours $n = 11$ dogs, 10 cats
pH	7.36–7.46 (D)	7.37 ± 0.09	7.39 ± 0.05	7.40 ± 0.05	7.39 ± 0.04
	7.25–7.43 (C)	7.34 ± 0.10	7.38 ± 0.00	7.40 ± 0.10	7.41 ± 0.00
HCO_3^- (mmol/L; mEq/L)	16–28 (D)	22.1 ± 3.9	22.1 ± 3.5	21.2 ± 2.7	21.7 ± 2.9
	15–27 (C)	21.9 ± 3.0	22.9 ± 2.8	23.9 ± 2.4	24.7 ± 1.3
P_vCO_2 (mm Hg)	30–47 (D)	39.1 ± 10.3	36.3 ± 8.4	33.6 ± 3.9	35.4 ± 4.2
	31–51 (C)	40.9 ± 5.6	38.5 ± 5.1	39.1 ± 7.6	39 ± 3.4
Chloride (mmol/L; mEq/L)	106–127 (D)	115 ± 6.1	116 ± 5.1	117 ± 5.8	117 ± 4.3
	111–128 (C)	118 ± 4.5	117 ± 4.8	118 ± 5.2	116 ± 4.7
Corrected chloride (mmol/L; mEq/L)	(D)	115 ± 4.1	115 ± 3.8	116 ± 4.0	115 ± 1.6
	(C)	118 ± 3.2	117 ± 1.9	117 ± 2.2	116 ± 2.5
Base excess (mmol/L; mEq/L)	−5–5 (D)	−3.2 ± 4.2	−2.8 ± 3.5	−3.8 ± 2.5	−3.2 ± 3.4
	−5–2 (C)	−3.9 ± 3.8	−2.1 ± 3.0	−0.9 ± 2.3	0.1 ± 1.5

*Reference and reportable ranges from Heska Element POC.
C, cat; D, dog.

Table 5: Serum venous blood gas values and chloride concentrations (mean and standard deviation) in dogs and cats that did not have a nasogastric tube (NGT) placed

	Reference intervals*	0 hours $n = 26$ dogs, 4 cats	12 hours $n = 26$ dogs, 4 cats	24 hours $n = 15$ dogs, 4 cats	36 hours $n = 5$ dogs, 2 cats
pH	7.36–7.46 (D)	7.39 ± 0.08	7.41 ± 0.04	7.42 ± 0.05	7.45 ± 0.04
	7.25–7.43 (C)	7.30 ± 0.11	7.36 ± 0.07	7.33 ± 0.12	7.38 ± 0.05
HCO_3^- (mmol/L; mEq/L)	16–28 (D)	20.7 ± 3.7	21.7 ± 2.9	22.3 ± 2.6	18.7 ± 2.9
	15–27 (C)	19.6 ± 5.4	20.0 ± 5.3	20.0 ± 4.8	22.6 ± 1.1
P_vCO_2 (mm Hg)	30–47 (D)	34.1 ± 6.1	34.4 ± 6.3	34.8 ± 5.8	27.5 ± 5.9
	31–51 (C)	38.9 ± 6.8	35.5 ± 9.9	37.0 ± 2.1	38.6 ± 2.6
Chloride (mmol/L; mEq/L)	106–127 (D)	113 ± 2.8	114 ± 4.3	115 ± 4.0	117 ± 2.2
	111–128 (C)	116 ± 6.4	117 ± 2.6	119 ± 2.6	120 ± 0.0
Corrected chloride (mmol/L; mEq/L)	(D)	115 ± 2.6	115 ± 3.6	115 ± 2.6	118 ± 1.7
	(C)	118 ± 1.8	122 ± 6.3	120 ± 2.8	119 ± 0.7
Base excess (mmol/L; mEq/L)	−5–5 (D)	−4.3 ± 4.3	−3.0 ± 2.8	−2.2 ± 2.7	−5.4 ± 2.4
	−5–2 (C)	−6.7 ± 6.9	−5.5 ± 5.8	−5.9 ± 6.7	−2.6 ± 2.0

*Reference and reportable ranges from Heska Element POC.
C, cat; D, dog.

among sample times and between dogs and cats, venous blood gas and electrolyte levels varied based on the age of the animal; HCO_3^- ($P = 0.049$) and P_vCO_2 ($P = 0.008$) decreased with age. Chloride ($P = 0.0006$) and CoCl ($P = 0.015$) increased with age.

There were no significant gender-associated differences in serum venous blood gas, chloride, or CoCl values in either the NGT or NoNGT groups, and gender was not a confounder in any subsequent analysis.

Venous blood gas and serum chloride concentrations in patients with NGT placement

Serum venous blood gas, chloride, and CoCl values in the NGT group were compared between samples collected at baseline and 12, 24, and 36 hours post-NGT placement. After correcting for differences associated with age and species, blood pH varied over time ($P = 0.023$). The pH value was higher at 12 hours (difference = 0.03 pH units, 95% CI 0.002 to 0.06, $P = 0.039$), 24 hours (0.04, 95% CI 0.02 to 0.07, $P = 0.001$), and 36 hours (0.05, 95% CI 0.02, to 0.08, $P = 0.0006$) after NGT placement than at baseline (mean = 7.36, SE = 0.013). The pH value was also higher at 36 hours after NGT placement compared to 12 hours ($P = 0.05$). There were no significant changes in the HCO_3^-, P_vCO_2, BE, chloride, and CoCl during the observation period before or after accounting for differences in age and species.

Comparison of venous blood gas and serum chloride between the NGT group and the NoNGT group

The P_vCO_2 was lower in the NGT group when compared to the NoNGT group. Across all sample times, P_vCO_2

was lower in the NGT group when compared to the NoNGT group (–2.78 mm Hg, 95% CI –0.34 to 5.22, $P = 0.03$). However, there was no significant change in P_vCO_2 over time in either group, and the amount of difference in P_vCO_2 between patients in the NGT and NoNGT group did not vary over time, either before or after accounting for differences in patient age and species. There was no significant difference between patients in the average value or difference in change over time of pH, HCO_3^-, BE, chloride, or CoCl during the 36-hour observation window.

Volume of gastric fluid aspirated and prokinetic therapy in the NGT group

Mean ± SD total volume of gastric fluid aspirated in dogs was 0.9 ± 1.2 mL/kg/h (median 0.43 mL/kg/h, range of 0–4.4 mL/kg/h). Mean ± SD total volume of gastric fluid aspirated in cats was 1.8 ± 3.0 mL/kg/h (median 0.48 mL/kg/h, range of 0–10.51 mL/kg/h). Table 3 groups patients based on the reasons for NGT placement and reports the mean volume of gastric fluid aspirated.

After adjusting for differences in age and species, serum venous blood gas, chloride, and CoCl values were not significantly associated with the volumes of gastric fluid aspirated over the 36-hour observation window. The use of prokinetic agents was also not significantly associated with the total volume of fluid aspirated from the NGT.

Prokinetic agents and changes in venous blood gas, serum chloride, and CoCl

In the NGT group, treatment included administration of a prokinetic agent (cisapride[k] $n = 17$, metoclopramide[l] $n = 14$). Prokinetic agents were administered in 19/23 (83%) dogs and 11/12 (92%) cats after NGT placement. In the NoNGT group, 8/26 (31%) dogs and 1/4 (25%) cats received a prokinetic agent (cisapride $n = 3$, metoclopramide $n = 6$).

Regardless of age or species, administration of a prokinetic agent did not result in a difference in serum venous blood gas, chloride, or CoCl values at any time point in the NGT group. However, the pH was slower to increase in patients treated with prokinetic agents ($P = 0.049$) compared to those not treated with prokinetic agents.

Potassium supplementation and changes in venous blood gas and electrolytes

In the NGT group, KCl[m] was supplemented in 4/23 (17.4%) dogs and 2/12 (16.7%) cats. In the NoNGT group, 1/26 (4%) dogs and 2/4 (50%) cats received KCl supplementation. In the NGT group, patients that were supplemented with KCl had lower average serum potassium concentration (–0.55 mmol/L, 95% CI 0.35 to 0.76, $P = 0.004$) than those that were not supplemented after accounting for differences in species and age. Supplementation with KCl was not associated with differences in any other serum venous blood gas or electrolyte concentrations in patients following NGT placement, including chloride and CoCl after accounting for differences in species and age.

Discussion

Canine experimental models of continuous gastric aspiration and induced pyloric obstruction will produce HCMA.[25,26] Additionally, HCMA can be experimentally induced in healthy dogs by selective depletion of hydrochloric acid through intermittent drainage of gastric fluid.[27] The current study indicates that intermittent NGT aspiration does not appear to be strongly associated with the development of HCMA for a period of up to 36 hours in dogs and cats admitted to the ICU.

In the NGT group, blood pH varied over time and was found to be significantly higher at all time points after NGT placement than at baseline. However, blood pH remained within the reference range for dogs and cats, and there was no corresponding significant decrease in P_vCO_2 or increase in HCO_3^-. It is possible that an alkalemia would have developed if the intermittent NGT aspiration were continued past the 36-hour observation window. The pH did increase more slowly with the use of a prokinetic, despite their lack of effect on gastric residual volumes within the observational window. It is possible that treatment with a prokinetic might mitigate development of an alkalemia. Because there was no significant change in either chloride or HCO_3^- after NGT placement, this study was not able to evaluate whether the use of prokinetics would be effective in preventing an HCMA in dogs and cats with NGTs.

The average P_vCO_2 across all time points, including baseline, was significantly lower in the NGT group when compared to the NoNGT group; however, there was no significant change in P_vCO_2 over time in either group, and the difference in P_vCO_2 between patients in the NGT and NoNGT group did not vary over time, despite the increase in pH over time. There was no associated decrease in baseline HCO_3^- to explain this difference. It is unclear why this difference was seen, and a difference might be eliminated with a larger study population. It is possible that the NGT group may have had patients with an underlying pulmonary disease process, centrally mediated hyperventilation, or hypoxemia that played a role in the decreased P_vCO_2. This difference could also be a type 1 error as the result of the large number of outcomes measured in this study.

Potassium chloride supplementation in the NGT group was not significantly associated with changes in serum venous blood gas or chloride values. The number of patients in the NoNGT group ($n = 3$) that received potassium supplementation was too low to allow comparison between the NGT and NoNGT groups.

Two patients received a dopamine constant rate infusion with 0.9% NaCl and 9 patients received hydroxyethyl starch based in 0.9% NaCl. These solutions contain no buffering agents and have high sodium and chloride concentrations (154 mmol/L [154 mEq/L] each), which could have affected venous blood gas and serum sodium and chloride levels. It is unknown if the concurrent use of 0.9% NaCl would affect serum venous blood gas and chloride, and the sample size is too small to interpret in this study.

NGT feeding was initiated in the NGT group patients, but at variable rates, with variable tolerance. Voluntary feeding was not restricted in the NoNGT group. Although no HCMA occurred, the effect of enteral nutrition on venous blood gas, serum chloride, and CoCl levels, as well as residual gastric volumes could potentially influence the results. Although the study power and the limited data available prevented exploration of the effect of enteral nutrition and gastric residual volumes, this study was meant to reflect the typical patient in the ICU setting, in which early enteral nutrition is encouraged.

The limitations of this study included the small sample size of ICU patients where NGT placement was indicated during the study period, the available cases being a mix of both dogs and cats of different ages, the observation time being 36 hours or less (particularly in the NoNGT group, in which a large proportion of patients were not followed through to 36 hours), the few number of animals with high gastric residual volumes, and a lack of control for adjunctive treatments and interventions due to the small number of animals in each treatment subgroup. The dogs and cats eligible for the study presented with a wide range of disease processes that had unknown influence on the risk of developing HCMA. This study was meant to provide a snapshot of the typical ICU patient in which placement of an NGT was recommended. Since the average length of NGT use was not beyond 36 hours, the data points were limited to up to 36 hours, and the conclusions are limited to patients having an NGT for up to 36 hours. Future controlled prospective studies with larger patient numbers or longer treatment times could potentially identify specific situations where NGT aspiration would result in a higher risk of clinically relevant HCMA.

In conclusion, there was no evidence in the current study that HCMA is a common and clinically relevant problem in hospitalized dogs and cats with NGT placement and intermittent aspiration up to 36 hours of NGT placement. These findings were supported by the comparison of venous blood gas and electrolyte results between patients with and without NGT placement. Despite the limited power, results of our statistical analysis suggest, with a 95% CI, that HCMA would not be expected to occur in more than 10% of patients in a similar ICU population within 36 hours of NGT placement.

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Footnotes

[a] Kangaroo Feeding Tube, Covidien LLC, Mansfield, MA.
[b] Nasogastric Tube - MILA International, Inc., Erlanger, KY.
[c] CliniCare Canine/Feline Liquid Diet, Abbott Animal Health, Abbott Park, IL.
[d] Element POC (Epoc analyzer), Heska, Loveland, CO.
[e] SAS ver 9.3, SAS Institute, Cary, NC.
[f] Plasmalyte-A Injection, Abbott, North Chicago, IL.
[g] Vetstarch 6% HES 130/0.4 in 0.9% NaCl injection, Abbott.
[h] Dextrose solution 50%, Nova-Tech, Inc., Grand Island, NE.
[i] Dopamine HCl Inj., USP, Hospira, Inc., Lake Forest, IL.
[j] 0.9% sodium chloride Injection USP, Abbott.
[k] Cisapride Compounded Oral Suspension, The Pet Apothecary, Glendale, WI.
[l] Metoclopramide Hydrochloride Injection, USP, Hospira, Inc., Lake Forest, IL.
[m] Potassium Chloride for Injection Concentrate, USP, Hospira, Inc.

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