Check for updates

ORIGINAL ARTICLE

Acid–base and electrolyte evaluation in dogs with upper GI obstruction: 115 dogs (2015-2021)

B. A. Lozano[1], I. Yankin, S. Perry and C. R. Rutter

Texas A&M University, Veterinary Medical Teaching Hospital, 408 Raymond Stotzer Pkwy, College Station, TX 77845, USA

[1]Corresponding author email: balozano17@gmail.com

Objectives: Metabolic alkalosis, although uncommon in small animals, has been previously associated with gastrointestinal obstructions. Depending on the population and disease process evaluated, previous prevalence of metabolic alkalosis is reported as ranging from 2% to 45% in canine patients. The objective of this study was to determine the prevalence of metabolic alkalosis and other acid–base and electrolyte disorders in a cohort of dogs with a confirmed upper gastrointestinal obstruction.

Materials and Methods: Electronic medical records were reviewed to identify dogs who presented for vomiting with evidence of an upper gastrointestinal obstruction from January 2015 to October 2021. Patients were enrolled only if a preoperative venous blood gas was obtained and analysed in house. Traditional acid–base analysis was utilised to determine an acid–base status before relieving the obstruction. When available, post-operative venous acid–base status was determined within 24 hours after surgery, and compared to preoperative results.

Results: A total of 115 dogs were included in the study. Twenty-five out of 115 (22%) dogs displayed either a simple metabolic alkalosis or a mixed acid–base disturbance before surgery. Twenty-seven out of 115 dogs (37%) had a normal acid–base status at entry. Seventy-one dogs had pre- and post-operative venous blood gas results available. Metabolic alkalosis was resolved in nearly all patients post-operatively, with no patients displaying a simple metabolic alkalosis. A mixed metabolic acidosis and respiratory alkalosis was the most common condition post-operatively, found in 25 of 71 (35%) dogs. Severe derangements of electrolytes were infrequent preoperatively (3/115; 2.6%). A majority of patients in this study exhibited hypokalaemia (64.4%), hypochloraemia (72.8%) and hyponatraemia (77.4%) on preoperative venous blood gases. Venous pH, P_vCO_2, bicarbonate and base excess were significantly higher preoperatively when compared to the post-operative results.

Clinical Significance: This study found the prevalence of pre-operative metabolic alkalosis in dogs with a documented upper gastrointestinal obstruction to be lower than previously reported. Surgical or endoscopic alleviation of the upper gastrointestinal obstruction resulted in resolution of metabolic alkalosis in nearly all patients.

Journal of Small Animal Practice (2023); **64**, 696–703
DOI: 10.1111/jsap.13656

Accepted: 29 June 2023; Published online: 10 August 2023

BSAVA JOURNAL OF SMALL ANIMAL PRACTICE JSAP

INTRODUCTION

Acute onset vomiting and gastrointestinal (GI) signs such as abdominal pain and diarrhoea are common clinical concerns of patients presenting for emergency evaluation. The GI tract is known to play a significant role in acid–base homeostasis, but literature describing acid–base and electrolyte changes in dogs with GI disease is limited (Koike *et al.* 1981, Guilford & Strombeck 1996, Boag *et al.* 2005, Gennari & Weise 2008). Generally, alkalosis occurs in the body secondary to the loss of acidifying components such hydrogen ions, carbon dioxide, and chloride. It has been proposed that profuse vomiting of stomach contents causes a loss of hydrogen ions, potassium and chloride contributing to a hypochloraemic (or chloride responsive) metabolic alkalosis (Guilford & Strombeck 1996, Dibartola 2012, Hall & Hall 2021). GI foreign bodies commonly result in vomiting and/or regurgitation (Figueiredo 2022). Chloride-responsive metabolic alkalosis (CRMA) is maintained in these patients by continued extracellular fluid volume depletion and renal retention of sodium and chloride (Dibartola 2012, Hopper 2015, Hall & Hall 2021).

Conversely, metabolic acidosis is more commonly associated with generalised GI disease (Guilford & Strombeck 1996, Boag *et al.* 2005). With wide spread GI disease, intestinal ischaemia and systemic hypoperfusion likely occur secondary to GI distress. This results in continued fluid loss through vomiting and increased GI secretions which leads to extracellular fluid loss resulting in in systemic hypoperfusion causing an elevated lactate, likely contributing to a metabolic acidosis (Rosenstein *et al.* 2018). In addition, diarrhoea may result in bicarbonate loss that will lead to a normal anion gap metabolic acidosis (Dibartola 2012). Because of the risk of electrolyte and acid–base derangement, it is vital to assess and select therapy to manage these conditions in patients with GI disease and/or obstruction before anaesthesia and intervention.

Some studies have evaluated acid–base derangements in veterinary patients and disease processes in which they occur (Ha *et al.* 2013). Despite the common understanding that dogs with obstruction of the pylorus or duodenum can present with a CRMA, there are few studies in the veterinary literature to support this conclusion (Boag *et al.* 2005). Incidence of metabolic alkalosis reported in this study was 45%; however, this was an evaluation of acid–base abnormalities in veterinary patients with obstructions in all parts of the GI tract (Boag *et al.* 2005). Veterinary literature is lacking when evaluating traditional acid–base and determining the prevalence of a CRMA in patients with, specifically, upper GI obstructions. There are few studies which incorporate electrolyte abnormalities with acid–base analysis in veterinary patients with GI obstruction. (Boag *et al.* 2005). There is a lack of literature evaluating resolution of acid–base and electrolyte abnormalities in our targeted patient subset. The objective of this study was to determine the prevalence of metabolic alkalosis or other acid–base and electrolyte disorders in a cohort of dogs with a confirmed upper GI obstruction. Our secondary objective was to evaluate for changes or resolution of acid–base abnormalities post-operatively. We hypothesised that patients with upper GI obstructions, without prior therapy, would present with a metabolic alkalosis with concurrent hypokalaemia and hypochloraemia. For our secondary objective, we hypothesised patients' acid–base and electrolyte derangements would resolve or improve upon recheck venous blood gas post-operatively.

METHODS

Electronic medical records were searched and reviewed to identify dogs who presented for vomiting with evidence of a proximal GI obstruction from January 2015 to October 2021. Dogs were included if they had a radiographically or surgically confirmed GI obstruction within the pylorus or duodenum and a venous blood gas analysis performed at our facility before relieving the obstruction. Patients that received definitive therapy at other facilities were included if radiographic or ultrasonographic confirmation of obstruction within our regions of study was performed by a board-certified radiologist. We did not exclude patients which had additional foreign bodies located elsewhere in the GI tract, so long as the obstructing foreign material was designated to be in the pylorus or duodenum. Patients who received prior therapy from the referring veterinarian were also included. Records were excluded if the patient had no history of vomiting, the patient was euthanased before relieving the obstruction, the obstruction was a mass lesion or neoplastic in origin, or the obstructing foreign body was not located within the pylorus or duodenum.

Demographic and clinicopathologic data obtained from medical records included age, breed, sex, reproductive status, location of obstruction, and venous blood gas variables before and after surgery (when available). Location of obstruction was obtained from surgical reports. Patients who did not have foreign body removal at the Veterinary Medical Teaching Hospital (VMTH) could still be included in the study if the location of the obstruction was confirmed with abdominal radiography or ultrasonography evaluated by a board-certified radiologist.

Venous blood samples were collected upon entry to the VMTH, before administration of intravenous fluids therapy. Venous blood gas and electrolyte analyses were conducted on a point of care analyser (Stat Profile pHOx Ultra Analyzer; Nova Biomedical Corporation, Waltham, MA, USA). All venous samples were heparinized and evaluated immediately after sample collection on the same analyser. Specific measured data obtained from the venous blood gas included: blood pH, partial pressure of venous carbon dioxide (P_vCO_2), sodium, potassium, and chloride. Calculated values included bicarbonate (HCO_3) and base excess (BE). Bicarbonate and BE are calculated by the analyser by applying the Henderson-Hasselbalch equation and Van Slyke equation [BE=(HCO_3^-)−25+16.2 (pH−7.4)], respectively. Reference ranges for the analyser had been previously determined and validated from a cohort of clinically normal dogs (pH, P_VCO_2, sodium, potassium, chloride, lactate) (Schmitz *et al.* 2021). Standard published reference ranges were used for PCV, total solids (TS), base excess, bicarbonate, and anion gap (Bonagura &

17485827, 2023, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/jsap.13656 by Universidad De Zaragoza, Wiley Online Library on [08/12/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Twedt 2013). Blood samples for this analysis must have been collected and analysed within 12 hours before removing the obstruction.

Traditional acid–base analysis was utilised to determine an acid–base status of each subject before relieving the obstruction. The acid–base diagnosis of each dog was determined via the traditional approach using previously published equations (Hopper 2015, Osborne *et al.* 2021). Given that previously obtained and assigned local reference intervals for blood gas and acid–base variables were available, the published equations were modified as follows (Table 1). Local reference intervals (RI) were obtained for this analyser via a transference study, performed when the machine was established in this hospital. Some reference intervals were not established on this analyser, namely bicarbonate and base excess, for these RI we utilised: Determination of reference intervals of acid–base parameters in clinically healthy dogs, by Vanova-Uhrikova et al. A metabolic acidosis was defined as a pH of less than 7.38 with a bicarbonate (HCO_3^-) less than 21.2 mmol/L, compensation was evaluated utilising the following equation: Partial venous pressure of carbon dioxide (P_vCO_2)=35.3–[(24.5–measured HCO_3^-)×0.7] ±3. Metabolic alkalosis was defined as a pH greater than 7.49 with a HCO_3^- greater than 27.8 mmol/L, P_vCO_2=35.3+[(Measured HCO_3^-–24.5)×0.7] ± 3, was utilised to determine compensation. For respiratory acidosis a pH of less than 7.38 with a P_vCO_2 greater than 40.8 mmHg, compensation was evaluated utilising HCO_3^-=24.5+[0.25×(35.3–measured P_vCO_2)] ±2. Respiratory alkalosis was defined as a pH greater than 7.49 with a P_vCO_2 less than 29.8 mmHg, HCO_3^-=24.5–[0.35×(35.3–measured P_vCO_2)] ±2 was utilised to evaluate for compensation. When response of the secondary system was not within the predicted range it was assigned a mixed acid–base status based on derangements in HCO_3^- and P_vCO_2. Due to the inability to determine chronicity of respiratory acid–base disturbances, when evaluating metabolic compensation, the acute and chronic compensation factors were averaged and utilised. Based on these calculations, each patient was assigned an acid–base status. Statuses were outlined as follows: metabolic acidosis, metabolic alkalosis, respiratory acidosis, or respiratory alkalosis. If compensation was not adequate, a mixed acid–base status was assigned.

Table 1. Equations used for evaluating compensation of acid–base abnormalities

Traditional acid–base analysis
Simple disturbances
1. Metabolic acidosis: pH<7.38, HCO_3^-<21.2 mmol/L, P_vCO_2=35.3–[(24.5–measured HCO_3^-)×0.7] ±3
2. Metabolic alkalosis: pH>7.49, HCO_3^->27.8 mmol/L, P_vCO_2=35.3+[(measured HCO_3^-–24.5)×0.7] ±3
3. Respiratory acidosis: pH<7.38, HC P_vCO_2>40.8 mmHg HCO_3^-=24.5+[0.25×(35.3–measured P_vCO_2)] ±2
4. Respiratory alkalosis: pH>7.49, HC P_vCO_2<29.8 mmHg HCO_3^-=24.5–[0.35×(35.3–measured P_vCO_2)] ±2
5. Mixed disturbances: Response in the secondary system not within predicted range

Electrolyte concentrations, specifically sodium, potassium and chloride included in the venous blood gas were recorded and evaluated. Electrolyte concentrations were classified as decreased, normal, or increased when related to the in-house reference intervals (Table 3). A corrected chloride was calculated using the equation: Cl^- (corrected)=Cl^- (measured)×[Na^+ (normal)÷Na^+ (measured)] (Autran de Morais & Biondo 2012). Severity of sodium and potassium derangements was evaluated. Severe hyponatraemia was classified as less than 125 mmol/L; severe hypokalaemia classified at less than 2.5 mmol/L (Ueda *et al.* 2015).

Incidence of comorbidities such as patient conformation (*i.e.*, brachycephalic dogs), cardiovascular disease (*i.e.*, congestive heart failure requiring loop diuretics) and patients with renal disease (*i.e.*, improper filtration of electrolytes). Current medications and previous therapies with the referring veterinarian (rDVM) that may contribute to alterations in acid–base status were recorded. Therapies that were suspected to alter acid–base status included: previous intravenous fluid therapy with rDVM before initial venous blood gas and loop diuretics.

When available, a post-operative venous blood gas panel measured between 4 and 24 hours of foreign body removal and recovery from general anaesthesia, was evaluated for acid–base status and compared to the preoperative panel. Data collection and traditional acid–base analysis were performed in the same fashion and compared to preoperative results.

Statistical analysis was performed via commercially available software (SAS version 9.4). Normality was determined using Kolmogorov–Smirnov method and visual examination of histograms. Continuous variables are expressed as the mean ±standard deviation (sd) when normally distributed and as the median with the minimum and maximum range (min to max) when non-normally distributed. Categorical data are presented as absolute numbers and percent frequencies. A 95% confidence interval for the mean or median difference between pre- and post-operative correlated continuous variables were reported. Significant proportional bias was considered present if the 95% CI for the slope of the regression line did not include 1, and significant constant bias was considered present if the 95% CI for the y-intercept did not overlap 0.

RESULTS

A total of 115 dogs satisfied all study criteria. The median age of dogs was 2 years (0.08 to 12), and median weight was 22.8 kg (1.16 to 57.8). There were 57 neutered males, 18 intact males, 33 neutered females and seven intact females. Labrador retrievers were the most common breed included in the study with 24 out of 115 (21%), followed by mixed breed (16/115; 14%), English bulldogs (9/115; 8%) and golden retrievers (8/115; 7%). Five out of 115 (4%) were pitbull terriers, followed by corgis and Australian shepherds (4/115; 4%, each).

The most common obstruction removal procedure performed was a gastrotomy (51/115; 44.3%), followed by a gastrotomy combined with a jejunotomy/ileotomy (22/115; 19.2%). The remainder of procedures were as follows: duodenotomy alone

17485827, 2023, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/jsap.13656 by Universidad De Zaragoza, Wiley Online Library on [08/12/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

(14/115; 12.2%), gastrotomy with duodenotomy (4/115; 3.5%), gastrotomy with intestinal resection and anastomosis (RA) (8/115; 6.9%), RA in the duodenum (6/115; 5.2%), therapy unreported at a different facility (6/115; 5.2%) and upper GI endoscopy (4/115; 3.5%).

The largest portion of dogs (42/115; 37%) had a normal acid–base status on admission to the emergency department. Twenty-five (22%) dogs displayed a simple metabolic alkalosis or mixed acid–base status before surgery, with 11 out of the 25 (10%) having a simple metabolic alkalosis and 14 (12%) having a mixed acid–base status with a component of metabolic alkalosis. Sixteen patients (14%) had a respiratory alkalosis, and the remainder of the dogs were as follows: mixed metabolic acidosis with respiratory alkalosis (15/115; 13%); simple metabolic acidosis (10/115; 9%); mixed metabolic alkalosis with respiratory alkalosis (9/115; 8%); mixed metabolic alkalosis with respiratory acidosis (5/115; 4%); simple respiratory acidosis (3/115; 3%); mixed metabolic acidosis with respiratory acidosis (2/115; 2%) (Fig 1). Preoperative clinicopathological variables were available for all included dogs (Table 2). Venous sodium, potassium and chloride concentrations were commonly below the reference interval, as reflected in Table 3. Severe hyponatraemia was found in two of 115 (1.7%) of patients, whereas severe hypokalaemia in one of 115 (0.86%). The patient with severe hypokalaemia had a concurrent severe hyponatraemia. All patients with a simple metabolic alkalosis exhibited a concurrent hypochloraemia.

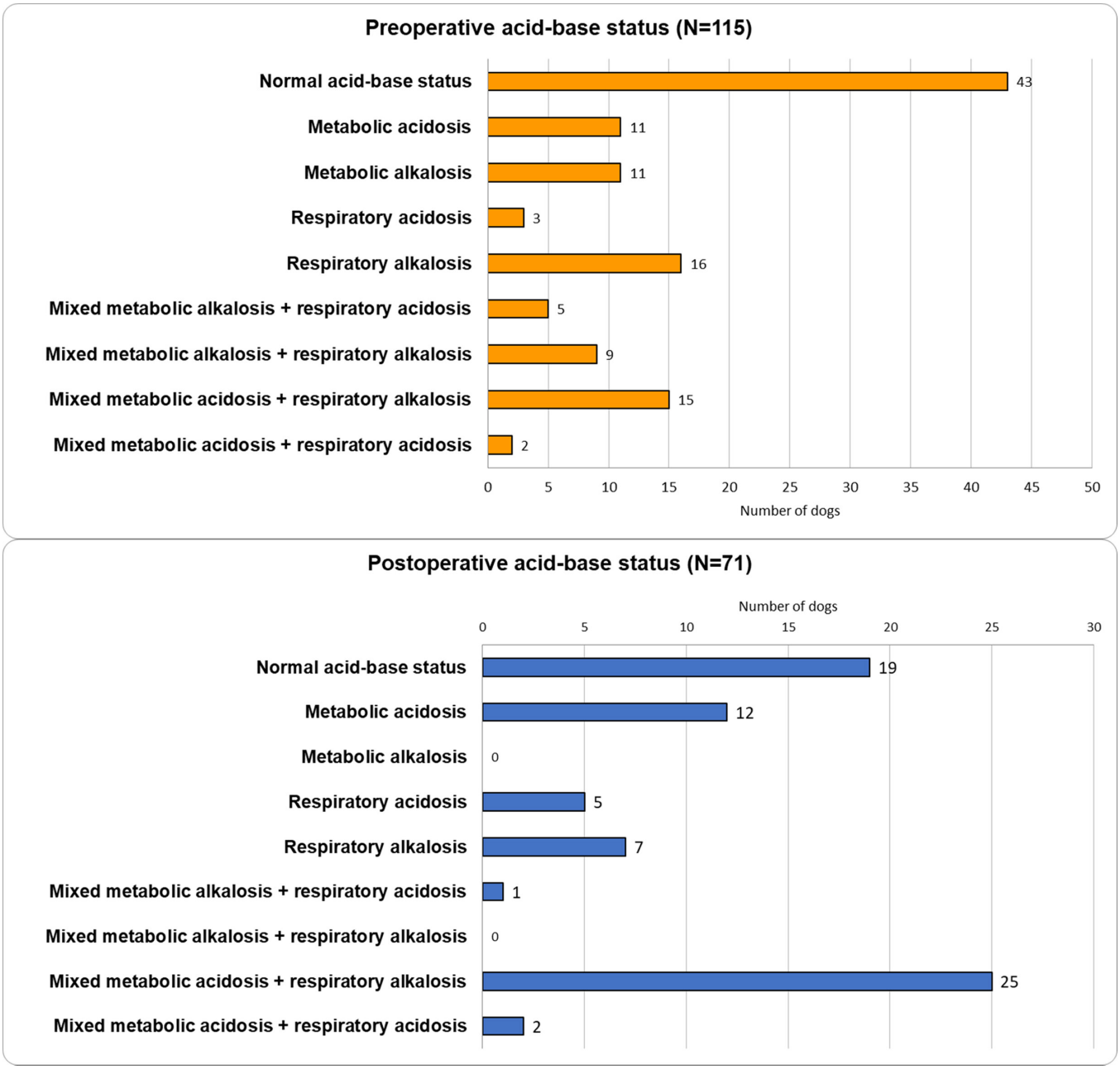


FIG 1. Comparison of all preoperative (115) *versus* post-operative (71) acid–base status in dogs with available venous blood gas results

17485827, 2023, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/jsap.13656 by Universidad De Zaragoza, Wiley Online Library on [08/12/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Comorbidities which may contribute to alterations in acid–base status were evaluated. Brachycephalic dogs accounted for 8.6% (10/115) of the patients included in our study. When evaluating their individual acid–base status, the most common was a respiratory alkalosis (3/10; 30%). Two dogs had a normal acid–base status, the remainder were as follows: two with a metabolic alkalosis; one with a metabolic acidosis; one with a mixed respiratory acidosis and metabolic alkalosis; one with a mixed metabolic acidosis and respiratory alkalosis.

When evaluating previous therapies and current medications which could have contributed to acid–base status, two patients included in our study were on loop diuretics for control of a congenital heart condition, pulmonic stenosis with right sided congestive heart failure in one, ventricular septal defect in the other. Acid–base status for those subjects was metabolic alkalosis and a mixed metabolic alkalosis and respiratory alkalosis, respectively.

Some patients (8.6%; 10/115) in our cohort received intravenous fluid therapy before presentation to the VMTH. The most common acid–base status in this cohort was normal (40%; 4/10). The remainder were as follows in order of frequency: two with respiratory alkalosis; metabolic alkalosis (2/10); metabolic acidosis (1/10); and metabolic acidosis with respiratory alkalosis (1/10).

No patients died secondary to their obstruction. When available, pre- and post-operative venous blood gas results were compared (Fig 2). Seventy-one out of 115 dogs had pre- and post-operative venous blood gas results. A smaller proportion of dogs were diagnosed with metabolic alkalosis after the alleviation of obstruction as compared to their acid–base status on presentation: 1/71 (1.4%; 95% CI, 0 to 4.2) vs. 16 of 71 (22.5%; 95% CI, 12.8 to 32.3). Post-operatively, a mixed metabolic acidosis and respiratory alkalosis was the most common condition, found in 25 of 71 (35%) dogs (Fig 1). Venous pH, bicarbonate and base excess were lower post-operatively, while chloride, corrected chloride, sodium and potassium were higher when compared to the preoperative results (Table 4).

Table 2. Clinicopathological variables in dogs with upper gastrointestinal obstruction before surgery (n=115)

Variables	Results (n=115)	Reference values
pH	7.45 (±0.05)	7.3 to 7.49
$PvCO_2$	32.3 (23 to 59.2)	29.8 to 40.8 mmHg
HCO_3	21.9 (14.6 to 45.9)	18.7 to 25.6 mmol/L (Vanova-Uhrikova *et al*. 2017)
Sodium	143.7 (121.1 to 154.3)	146.8 to 153.1 mmol/L
Potassium	3.75 (±0.46)	3.91 to 4.4 mmol/L
Chloride	107.8 (69.7 to 119.5)	110.6 to 115.5 mmol/L
Base excess	−2.2 (−11.7 to 22.4)	−6.0 to 0.4 mmol/L (Vanova-Uhrikova *et al*. 2017)

DISCUSSION

Our study aimed to provide further evaluation of acid–base and electrolyte abnormalities in patients with upper GI obstruction, specifically the duodenum and stomach. A wide variety of patients were included in the study. The most common signalment was a young, large breed dog (median age 4 years), consistent with previous retrospective studies evaluating GI disease with acid–base status (Boag *et al*. 2005).

Surgical or endoscopic alleviation of the obstruction, along with pre and post-operative fluid therapy, resulted in resolution of metabolic alkalosis and improvement in electrolyte derangements in nearly all patients. Derangements of electrolytes preoperatively were frequent, and should not be overlooked in this patient subset. All patients received some form of isotonic crystalloid fluid therapy during their time at the hospital. Some patients received electrolyte supplementation, most commonly potassium chloride solution diluted within the isotonic crystalloid solution. Due to the retrospective nature of our study, no conclusions were made in regards to type or duration of IV fluids and electrolyte supplementation before and after foreign body removal contributing to the resolution of acid–base abnormalities and/or improvement in electrolyte derangements.

Our study displayed similar findings as previous studies evaluating alkalosis in veterinary patients, with 21.7% (25/115) of our patients having some form of metabolic alkalosis. (Boag *et al*. 2005). There are few studies evaluating the incidence of metabolic alkalosis in veterinary patient with GI obstruction. Boag *et al*. reviewed the incidence of acid–base and electrolyte abnormalities in dogs with GI foreign bodies and found a higher prevalence of metabolic alkalosis than reported in the present study. Evaluation of the dogs in Boag *et al*. allowed for inclusion of dogs with foreign bodies regardless of location. Metabolic alkalosis, characterised by a supra-normal base excess was the most common acid–base abnormality in this study with 45.2% of patients (Boag *et al*.). There was no further breakdown of acid–base abnormalities to determine if the status was simple or mixed. In our study, 21.7% (25/115) of dogs had a simple or mixed metabolic alkalosis. We found a lower prevalence of simple metabolic alkalosis, present in 9.5% (11/115) of patients. Mixed metabolic alkalosis accounted for 12.1% (14/115) of patients in our cohort.

Comorbidities which may contribute to alterations in acid–base status were evaluated. Respiratory acidosis occurs in the face of hypoventilation (Dibartola 2012, Hopper 2015). This is secondary to carbon dioxide build up within the body, resulting in increased total body acid and subsequent decrease in pH (Johnson & Autran de Morais 2012). Brachycephalic breeds, due to their airway and

Table 3. Frequency of electrolyte derangements in dogs presented for upper gastrointestinal obstruction on preoperative bloodwork

Electrolyte	Decreased, n (%)	Normal, n (%)	Increased, n (%)	Number of dogs
Potassium (RI: 3.91 to 4.4 mmol/L)	74 (64.4)	32 (27.8)	9 (7.8)	115
Sodium (RI: 146.8 to 153.1 mmol/L)	89 (77.4)	25 (21.7)	1 (0.9)	115
Chloride (RI: 110.6 to 115.5 mmol/L)	83 (72.8)	21 (18.4)	10 (8.8)	114

RI Reference interval

17485827, 2023, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/jsap.13656 by Universidad De Zaragoza, Wiley Online Library on [08/12/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

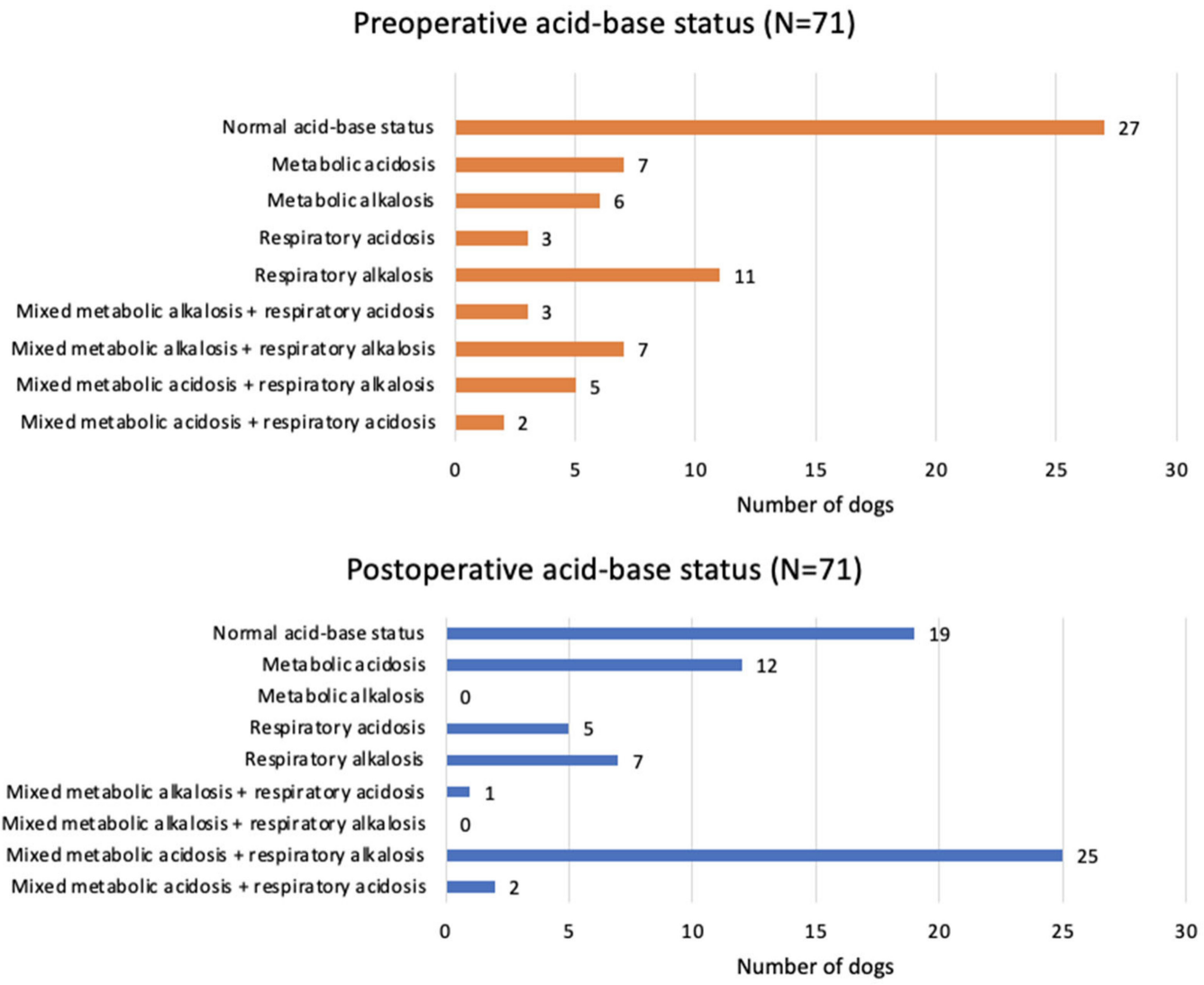


FIG 2. Comparison of preoperative *versus* post-operative acid–base status in 71 dogs with available venous blood gas results

Table 4. Comparison of preoperative and post-operative venous blood gas variables and electrolytes

Variables	Preoperative (n=71)	Post-operative (n=71)	Reference interval	Mean or median difference (95% CI)
pH	7.45 (±0.06)	7.41 (±0.06)	7.3 to 7.49	0.034 (0.02, 0.05)
$PvCO_2$	33 (23 to 49.6)	30.8 (20.7 to 58.4)	29.8 to 40.8 mmHg	1.3 (−0.2, 4.5)
HCO_3	23.5 (±4.4)	20.4 (±3.6)	18.7 to 25.6 mmol/L (Vanova-Uhrikova *et al*. 2017)	3.09 (2.23, 3.96)
Sodium	142.7 (±5.2)	143.9 (±4.8)	146.8 to 153.1 mmol/L	−1.25 (−2.3, −0.18)
Potassium	3.7 (±0.4)	3.84 (±0.4)	3.91 to 4.4 mmol/L	−0.17 (−0.27, −0.06)
Chloride	107.2 (80.2 to 118.6)	113.2 (98.7 to 136)	110.6 to 115.5 mmol/L	−5.45 (−6.6, −4.4)
Corrected chloride	111 (99.2 to 136.3)	117.7 (106.9 to 141)	110.6 to 115.5 mmol/L	−5.6 (−6.8, −4.7)
Base excess	−1.9 (−11.7 to 13)	−4.6 (−12.5 to 7.1)	−6.0 to 0.4 mmol/L (Vanova-Uhrikova *et al*. 2017)	2.8 (1.9, 4.2)

CI Confidence interval

chest confirmation, are notorious for hypoventilation, especially in the face of illness (Mitze *et al*. 2022). The body has mechanisms in place to compensate for this chronic respiratory acidosis. When hypercapnia persists for more than 5 days, renal compensation will occur increasing H^+ excretion while simultaneously increasing bicarbonate reabsorption (Johnson & Autran de Morais 2012).

17485827, 2023, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/jsap.13656 by Universidad De Zaragoza, Wiley Online Library on [08/12/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Brachycephalic dogs accounted for 8.6% (10/115) of the patients included in our study. Only one patient classified as brachycephalic exhibited a component of respiratory acidosis. This patient has concurrent aspiration pneumonia at the time of presentation. Previous airway surgery could have contributed to this finding in our cohort of patients, but it was impossible to know which dogs had this before admission to our facility.

There was a population of patients (8.6%) who received intravenous fluid therapy before presentation to the VMTH. Venous blood gases in these patients would have been obtained post intravenous fluid therapy, but it was impossible to quantify the amount and duration which those patients received those therapies. This could have altered acid–base status in these patients before presentation, as chloride replacement *via* intravenous fluid therapy is a mainstay of therapy for CRMA (Hopper 2015). Almost half (40%) of the patients presenting with this history had a normal acid–base status. Two still presented with metabolic alkalosis in this subset, possibly they received less fluid therapy than those who presented with a normal acid–base status.

Decreased circulating volume and potassium deficiency are likely in our patient population since all dogs had vomiting as a clinical sign, and preoperative venous blood gas samples were typically obtained before the administration of intravenous fluids or electrolyte supplementation. It is interesting to note that a large portion (64.4%) patients in our study were hypokalaemic and all patients with a metabolic alkalosis had concurrent hypochloraemia, supporting the validity of the suggested pathophysiology in the development of CRMA.

While electrolyte derangements were common, severe derangements of sodium and potassium were infrequently recorded. Electrolyte imbalance can cause or contribute to patient morbidity, and should be addressed on a case-by-case basis (Ha *et al*. 2013). Potassium is essential for the balance and maintenance of skeletal muscle resting membrane potential and strength (Riordan & Schaer 2015). Severe hypokalaemia can lead to muscle weakness, hypoventilation, arrhythmia and decreased bicarbonate excretion in the proximal renal tubule (Riordan & Schaer 2015). Hypochloraemia can contribute to decreased renal bicarbonate excretion, potentially exacerbating the metabolic alkalosis (Hopper 2015). The vast role of sodium balance is beyond the scope of this discussion, but it bears mentioning that tight sodium regulation is essential to regulate total body water distribution, osmolality and basic cellular function (Burkitt Creedon 2015). Dysregulation of electrolytes such as sodium, potassium, and chloride globally contributes to mortality, with neurologic and cardiac sequalae being especially notable (Hall & Hall 2021). These electrolyte derangements can complicate clinical management and anaesthetic care of affected patients, motivating many clinicians to attempt to correct derangements before anaesthesia and correction of the underlying cause.

As mentioned above, the initial treatment for chloride-responsive alkalosis includes restoring the effective circulating volume and correction of potassium and chloride deficits (Hopper 2015). Definitive treatment for metabolic alkalosis lies in treating the underlying cause, although the body employs compensatory mechanisms to maintain acid–base balance (Dibartola 2012, Hopper 2015). In our study, surgical or endoscopic removal of the foreign body was pursued at our facility or elsewhere in all patients. Removal interventions required anaesthesia, and clinicians may have initiated therapy to correct fluid balance and electrolyte abnormalities to decrease anaesthetic risk. We recorded 71 subjects with post-operative venous blood gas analyses available for evaluation. Surgical or endoscopic alleviation of an upper GI obstruction resulted in resolution of metabolic alkalosis in nearly all patients. This is consistent with the previously mentioned physiologic and therapeutic knowledge of metabolic alkalosis (Dibartola 2012).

There were several limitations associated with this study. Dogs with concurrent upper GI and lower GI obstructions were not excluded, and we included patients that had surgery at other facilities if radiographic or ultrasonographic confirmation of obstruction within our regions of study was performed by a board-certified radiologist. We also included patients who underwent endoscopic removal of the obstruction if vomiting was a presenting clinical sign and a venous blood gas was evaluated. No patients died secondary to their obstruction; however, we did not include patients who were euthanased before surgical intervention. An additional limitation of this study is the lack of data addressing the duration of obstruction or clinical signs available for patients. Duration is likely to play a role in the severity of metabolic alkalosis, as physiologic compensatory mechanisms ultimately fail with persistence of obstruction. A prospective evaluation could be considered to further evaluate the role of persistence of clinical signs in the severity of metabolic alkalosis. It was not possible to extrapolate from our data whether electrolyte management was attempted or impacted measured values before anaesthesia for included patients. Further studies could consider evaluating the frequency and impact of preoperative electrolyte supplementation on patient management and outcome.

Although commonly associated with upper GI obstructions, our data suggest metabolic alkalosis occurs with similar frequency than previously reported, though some patients had statistically significant electrolyte derangements. Acid–base status and electrolyte data should be evaluated in patients with upper GI obstructions before anaesthesia and surgery. Physiologic compensatory mechanisms can become overwhelmed and take time to restore acid–base status on their own. Sodium, potassium and chloride were commonly below the reference interval, and while few were severe, it is possible that they could worsen without diligent fluid and surgical correction of the obstruction. Early evaluation of acid–base status and electrolyte values may allow for correction of severe derangements before surgical correction, potentially mitigating significant anaesthetic complications. Resolution of the obstruction resulted in improvement of preoperative derangements in a majority of the patients evaluated in this study. This improvement is likely attributed to the replacement of depleted chloride and potassium with intravenous fluid supplementation and resolution of the upper GI obstructions.

17485827, 2023, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/jsap.13656 by Universidad De Zaragoza, Wiley Online Library on [08/12/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Conflict of interest

None of the authors of this article has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Author contributions

Beth Anne Lozano: Data curation (lead); writing – original draft (lead). **Igor Yankin:** Formal analysis (lead); software (lead); writing – review and editing (equal). **Sarah Perry:** Data curation (equal). **Christine R. Rutter:** Conceptualization (lead); project administration (lead); resources (equal); supervision (lead); writing – review and editing (equal).

References

Autran de Morais, H. & Biondo, A. W. (2012) Chaper 4 – disorders of chloride: hyperchloremia and hypochloremia. In: Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice. 4th edn. Eds S. P. Dibartola and W. B. Saunders. Elsevier, Saint Louis, MO, USA. pp 80-91

Boag, A. K., Coe, R. J., Martinez, T. A., *et al*. (2005) Acid-base and electrolyte abnormalities in dogs with gastrointestinal foreign bodies. *Journal of Veterinary Internal Medicine* **19**, 816-821

Bonagura, J. D. & Twedt, D. C. (2013) Appendix VIII and XXIII. In: Kirk's Current Veterinary Therapy XV. Elsevier, Saint Louis, MO, USA

Burkitt Creedon, J. M. (2015) Chapter 50 – sodium disorders. In: Small Animal Critical Care Medicine. 2nd edn. Eds D. C. Silverstein and K. W. B. S. Hopper. Elsevier, Saint Louis, MO, USA. pp 263-268

Dibartola, S. P. (2012) Chapter 10 – metabolic acid-base disorders. In: Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice. 4th edn. Ed S. P. Dibartola. W.B. Saunders, Saint Louis, MO, USA. pp 253-286

Figueiredo, J. P. (2022) Chapter 5 – gastrointestinal disease. In: Canine and Feline Anesthesia and Co-Existing Disease. Eds R. A. Johnson, L. B. C. Snyder and C. A. Schroeder. Wiley-Blackwell, Madison, WI, USA. pp 155-201

Gennari, F. J. & Weise, W. J. (2008) Acid-base disturbances in gastrointestinal disease. *Clinical Journal of the American Society of Nephrology* **3**, 1861-1868

Guilford, W. G. & Strombeck, D. R. (1996) Intestinal obstruction, pseudo-obstruction, and foreign bodies. In: Strombeck's Small Animal Gastroenterology. 3rd edn. Ed W. B. Saunders. Saunders, Philadelphia, PA, USA. pp 487-502

Ha, Y. S., Hopper, K. & Epstein, S. E. (2013) Incidence, nature, and etiology of metabolic alkalosis in dogs and cats. *Journal of Veterinary Internal Medicine* **27**, 847-853

Hall, J. E. & Hall, M. E. (2021) Chapter 31 – acid-base regulation. In: Guyton and Hall Textbook of Medical Physiology. 14th edn. Eds A. C. Guyton, J. E. Hall and M. E. Hall. Elsevier, Philadelphia, PA, USA. pp 403-420

Hopper, K. (2015) Chapter 54 – traditional acid-base analysis. In: Small Animal Critical Care Medicine. 2nd edn. Eds D. C. Silverstein and K. W. B. S. Hopper. Elsevier, Saint Louis, MO, USA. pp 289-295

Johnson, R. A. & Autran de Morais, H. (2012) Chaper 11 – respiratory acid-base disorders. In: Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice. 4th edn. Eds S. P. Dibartola and W. B. Saunders. Elsevier, Saint Louis, MO, USA. pp 287-301

Koike, T., Otomo, K., Kudo, T., *et al*. (1981) Clinical cases of intestinal obstruction with foreign bodies and intussusception in dogs. *The Japanese Journal of Veterinary Research* **29**, 8-15

Mitze, S., Barrs, V. R., Beatty, J. A., *et al*. (2022) Brachycephalic obstructive airway syndrome: much more than a surgical problem. *The Veterinary Quarterly* **42**, 213-223

Osborne, L. G., Burkitt-Creedon, J. M., Epstein, S. E., *et al*. (2021) Semiquantitative acid-base analysis in dogs with typical hypoadrenocorticism. *Journal of Veterinary Emergency and Critical Care* **31**, 99-105

Riordan, L. L. & Schaer, M. (2015) Chapter 51 – potassium disorders. In: Small Animal Critical Care Medicine. 2nd edn. Eds D. C. Silverstein, K. Hopper and W. B. Saunders. Elsevier, Saint Louis, MO, USA. pp 269-273

Rosenstein, P. G., Tennent-Brown, B. S. & Hughes, D. (2018) Clinical use of plasma lactate concentration. Part 2: prognostic and diagnostic utility and the clinical management of hyperlactatemia. *Journal of Veterinary Emergency and Critical Care* **28**, 106-121

Schmitz, K. L., Jeffery, U., Heinz, J. A., *et al*. (2021) Evaluation of two benchtop blood gas analyzers for measurement of electrolyte concentrations in venous blood samples from dogs. *American Journal of Veterinary Research* **82**, 105-109

Ueda, Y., Hopper, K. & Epstein, S. E. (2015) Incidence, severity and prognosis associated with hypernatremia in dogs and cats. *Journal of Veterinary Internal Medicine* **29**, 794-800

Vanova-Uhrikova, I., Rauserova-Lexmaulova, L., Rehakova, K., *et al*. (2017) Determination of reference intervals of acid-base parameters in clinically healthy dogs. *Journal of Veterinary Emergency and Critical Care* **27**, 325-332

17485827, 2023, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/jsap.13656 by Universidad De Zaragoza, Wiley Online Library on [08/12/2025]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License