Cross-sectional study of the association of abomasal displacement or volvulus with serum electrolyte and mineral concentrations in dairy cows

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Abstract — The objective of this study was to evaluate serum mineral and electrolyte concentrations at the time of on-farm diagnosis of left displaced abomasum, right displaced abomasum, or abomasal volvulus in dairy cows. Data were collected from 104 affected cows and 96 control cows matched with cases, based on herd, parity, and stage of lactation. Cows with abomasal displacement or volvulus had significantly lower calcium, phosphorous, magnesium, potassium, and chloride concentrations and increased anion gap at the time of diagnosis compared with control cows from the same herds. The percentages of cases and controls with total serum calcium concentrations below the lower limit of the laboratory reference range (2.08 mmol/L [8.3 mg/dL]) were 70% and 23%, respectively. Based on the large percentage of cases with hypocalcemia, administering calcium salts at the time of treatment of field cases of abomasal displacement or volvulus may be beneficial.

Résumé — **Étude transversale de l'association d'un déplacement ou d'un volvulus de l'abomasum avec les concentrations sériques d'électrolytes et de minéraux chez les vaches laitières.** L'objectif de cette étude était d'évaluer les concentrations sériques de minéraux et d'électrolytes au moment du diagnostic sur la ferme d'un déplacement à gauche de l'abomasum, d'un déplacement à droite de l'abomasum ou d'un volvulus de l'abomasum chez des vaches laitières. Les données ont été recueillies à partir de 104 vaches atteintes et de 96 vaches témoins, associées selon la condition pathologique, en tenant compte du troupeau, du nombre de mises bas et du stade de lactation. Lorsque comparées aux vaches témoins des mêmes troupeaux, les vaches ayant un déplacement ou un volvulus de l'abomasum présentaient des concentrations significativement plus basses de calcium, de phosphore, de magnésium, de potassium et de chlorure et une augmentation du trou anionique au moment du diagnostic. Les pourcentages des malades et des témoins présentant des concentrations sériques totales de calcium en dessous de la limite inférieure de la fourchette de référence du laboratoire (2,08 mmol/L [8,3 mg/dL]) étaient respectivement de 70 % et 23 %. En se basant sur le fort pourcentage de cas présentant une hypocalcémie, l'administration de sels de calcium au moment du diagnostic sur la ferme des déplacements ou des volvulus de l'abomasum pourrait être bénéfique.

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Introduction

Abomasal displacement (DA) is among the most commonly encountered diseases in dairy veterinary practice. In a sample of dairy herds in New York State, the lactational incidence risk for DA was 6.3%, with a median time of occurrence of 11 d after calving (1). The lactational incidence rate of DA was 6% for first lactation cows and 7% for 2nd or greater lactation cows in a study of dairy herds in Michigan (2). Individual herd incidence rates for left displaced abomasum (LDA) ranged from 0% to 22% in a review of 8 studies (3). Economic effects of DA include treatment costs and potential effects on milk production, reproduction, and culling. Cows with LDA yielded 557 kg less milk from the time of calving to 60 d after diagnosis than did healthy cows (4). In another study, DA was associated with a decrease of 202 kg in milk production from calving to day 21 and 200 kg from days 22 to 49 in lactation (5). Displaced abomasum increased the risk of culling within the first 30 d after calving but did not have a significant effect on culling later in lactation (6). Identifying preventive measures for this condition and improving performance after treatment are economically important for the dairy industry.

The occurrence of DA is related to anatomical factors associated with parturition and rumen fill and with abomasal atony (7). Nutritional risk factors that have been identified include high energy diets, negative energy balance, and high body condition in the prepartum period (2). Other nutritional effects on DA were

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reviewed recently (3). Seasonal, parity, and disease effects on the occurrence of LDA have also been reported (2,8,9).

There has been a long-standing interest in the role of hypocalcemia in the pathogenesis of DA. Cows with hypocalcemia near the time of calving were found to be at increased risk of subsequent LDA (10). In another study, low serum calcium in the 2nd, but not the 1st, week postpartum was associated with an increased risk of LDA (11). Hypocalcemia could affect the incidence of DA directly by effects on abomasal motility or indirectly by increasing the occurrence of other diseases in early lactation, such as retained placenta or metritis. A threshold effect of hypocalcemia on abomasal motility was observed in one study (12), but a trend for motility to decrease as plasma calcium decreased was found in another (13). Decreased abomasal motility and other physiological effects of hypocalcemia at the time of treatment of DA could also influence performance after treatment. Hypocalcemia and other clinical chemistry abnormalities have been described for cases of DA seen at veterinary referral hospitals. Cows diagnosed with uncomplicated DA characteristically have a hypokalemic, hypochloremic, metabolic alkalosis (14). Blood chemistry evaluation of cows with LDA revealed decreases in potassium (K), magnesium (Mg), and calcium (Ca), with metabolic alkalosis recorded on certain days and metabolic acidosis recorded occasionally (15). In studies of hospitalized cows, serum chemistry for cows with LDA frequently showed decreased K, chloride (Cl), and Ca (16,17) and increased concentrations of phosphorous (P) and Mg (16). In contrast to previous hospital-based investigations, a recent study found no relationship between displaced abomasum and hypocalcemia (18).

The objective of our study was to evaluate serum electrolyte and mineral concentrations at the time of on-farm diagnosis of DA or volvulus in commercial dairy herds. Our primary purpose was to estimate the prevalence of hypocalcemia in cows with these conditions, in order to evaluate the likelihood that administration of Ca salts would have a beneficial effect on recovery.

Materials and methods

Cows were enrolled in the study by Cornell University Ambulatory and Production Medicine Service clinicians when they diagnosed LDA, right displaced abomasum (RDA), or abomasal torsion (RTA) from May 7 to December 10, 1997. The Ambulatory and Production Medicine Service provides clinical service to dairy farms in a 35-mile radius of Ithaca, New York. Left displaced abomasum was diagnosed by hearing a characteristic "ping" under the left rib cage upon simultaneous percussion and auscultation. Right displaced abomasum and RTA were tentatively diagnosed by hearing a ping under the rib cage on the right side as far craniad as the 9th rib and were usually confirmed at surgery. Control cows were selected by asking herd owners or managers to identify a healthy cow within the same lactation group (1st, 2nd, or ≥ 3rd) and with the closest previous calving date to the cow diagnosed with DA. If no cows in the same lactation group were available, a control cow as close in age and calving date as possible was chosen. Dry cows were matched by lactation group and due date. Healthy cows were defined as not having been presented for veterinary examination because of being sick on the day of the visit and not currently being treated for illness by farm personnel.

Approximately 10 mL of whole blood was collected from the coccygeal or jugular vein into vacutainer tubes prior to treatment of cases and as soon as possible from matched controls. The date, time, and route of administration were recorded for cows that had received Ca therapy in the previous 72 h.

Blood samples were brought back to the clinic and then refrigerated until serum was harvested, placed in plastic tubes, and frozen at -20°C. Total serum Ca, P, Mg, K, sodium (Na), Cl, bicarbonate, and anion gap were measured by the College of Veterinary Medicine Clinical Pathology Laboratory. Calcium, P, bicarbonate, and Mg were measured by using standard methods and reagents (Boehringer Mannheim, Indianapolis, Indiana, USA) on an automated chemistry analyzer (Hitachi 911, Boehringer Mannheim). Sodium, K, and Cl were measured by using indirect potentiometry on the same analyzer. The anion gap was calculated from the measured Na, K, Cl, and bicarbonate values.

The analyses of the data were done by using a statistical microcomputer program (SAS v. 6.12, SAS Institute, Cary, North Carolina, USA). The mean and the standard deviation were calculated for case and control cows for each analyte. The relationship between case and control status and serum chemistry values were analyzed individually for each serum chemistry value by using PROC MIXED in SAS. Cow-pair was included in these models as a random effect. Plots and normality of residuals were used to evaluate model assumptions. The association of DA with the cow having analyte measurements below the lower limit of the laboratory reference range was evaluated by using the McNemar test and calculating odds ratios and 95% confidence intervals for pair matched data. The same methods were used to test the relationship of DA with bicarbonate and anion gap measurements exceeding the upper limit of the laboratory reference range. A microcomputer program for the analysis of epidemiologic data was used for these calculations (Epi Info v.6.04b, Centers for Disease Control, Atlanta, Georgia, USA).

Results

Samples were collected from 104 cases on 28 farms. These represented 58% of the cases diagnosed with LDA, RDA, or RTA during the same period, based on clinic billing records. Cows were not included in the study when herd owners did not want to participate, clinicians forgot to collect samples, or work schedules did not permit sample and data collection. Herds were diverse with respect to size (30–1300 milking cows), housing, and nutritional management, but all consisted mostly of Holstein cows, produced Grade A milk, and, with one exception, were privately owned (cows from the Cornell Teaching and Research dairy were included in

Table 1. Serum mineral and electrolyte concentrations for cows with abomasal displacement or volvulus and control cows matched by herd, stage of lactation, and parity on 28 dairy farms in New York State

	Cases (n = 103)		Controls (n = 96)	
Analyte (mmol/L)	$\bar{x}$	s	$\bar{x}$	s
Calcium	2.0	0.2	2.2	0.3
Phosphorous	1.8	0.6	2.0	0.4
Magnesium	0.8	0.2	0.9	0.2
Sodium	138	8.1	139	5.8
Potassium	4.7	1.0	5.1	0.8
Chloride	96	8.2	99	4.8
Bicarbonate	23.5	5.5	23.4	2.6
Anion gap	23.7	4.9	21.0	2.8

Table 2. Effect of abomasal displacement or volvulus on serum electrolyte and mineral concentrations (estimates controlling for cow pairs matched by herd, stage of lactation, and parity)

Analyte (mmol/L)	Mean difference (Case-control)	95% Confidence interval		% Change from control group mean
		Lower bound	Upper bound	
Calcium	−0.2	−0.3	−0.2	−9.6
Phosphorous	−0.2	−0.4	−0.1	−11.5
Magnesium	−0.05	−0.09	−0.01	−5.9
Sodium	−0.6	−2.5	1.4	−0.4
Potassium	−0.4	−0.6	−0.2	−8.6
Chloride	−3.8	−5.5	−2.1	−3.8
Bicarbonate	0.1	−1.0	1.3	0.5
Anion gap	2.6	1.6	3.7	12.6

the study). The number of cases per farm ranged from 1 to 17 (median = 2).

The number of cows diagnosed with LDA, RDA, and RTA were 91, 6, and 7, respectively. The percentages of cases in 1st, 2nd, and 3rd or greater lactation were 29%, 14%, and 57%, respectively. About 80% of cases were diagnosed within 30 d after calving (range 14 d before calving to 362 d after calving, median = 14 d after calving). Samples were obtained from 96 matched controls (control samples were not available for 8 cases). The median difference in days in milk between cases and matched controls was −0.5 (range −60 to 40). The days in milk were within 2 wk of the case for 85% of control cows. Eighty-seven percent of matched controls were in the same lactation group as cases. Seven cases were known to have received Ca salts within 72 h preceding sample collection. One of these was given calcium borogluconate less than 1 h before collecting the blood sample for the study and was excluded from statistical analyses of the relationship between abomasal disorders and serum minerals or electrolytes. Only one cow was enrolled twice in the study, first as a control and then as a case (data from this cow were not excluded because inclusion criteria were met in both instances).

Serum was collected from 82% of samples within 24 h of drawing blood, 16% from 24 to 48 h, and 2% from 48 to 65 h. Serum K concentration and anion gap were positively correlated with the interval from drawing blood to serum collection (Spearman's rho = 0.4, P = 0.0001, and 0.2, P = 0.04, respectively). Samples were held frozen at -20°C for a median of 22 d before laboratory analysis (range 1 to 218 d). Some analyte measurements were moderately correlated with time from freezing the sample until analysis. Phosphorous and bicarbonate concentrations were negatively correlated with freezer storage time (Spearman's rho = -0.1, P = 0.05 and rho = -0.3, P = 0.0001, respectively). Sodium and Cl concentrations, and anion gap were positively correlated with freezer storage time (Spearman's rho = 0.2, P = 0.009, rho = 0.2, P = 0.02, and rho = 0.2, P = 0.003, respectively).

Cows with DA or RTA had significantly lower Ca, P, Mg, K, and Cl concentrations and higher anion gap at the time of diagnosis compared with healthy cows from the same herds ($P < 0.05$). The mean Na and bicarbonate concentrations were not different for cases and controls ($P > 0.5$). Table 1 shows the means and standard deviations for the serum chemistry values measured. The mean differences between cases and control cows are shown in Table 2. Examination of the distribution of residuals and residuals plots showed that the model assumptions were adequate for most of the analytes. The independence of residuals was improved for the bicarbonate and anion gap models by including freezer storage time as an explanatory variable and for the K model by including the time from blood collection to serum collection. Addition of these variables did not cause important changes in the estimates of case-control differences and confidence intervals. Therefore, the results from the simpler models are reported. The residuals for Mg appeared to be correlated and were unchanged when other explanatory variables were included in the model. Seventy percent of affected cows had total serum Ca concentrations below the lower limit of the laboratory reference range (2.08 mmol/L

Table 3. Percentages of abnormal serum mineral and electrolyte concentrations for cows with abomasal displacement or volvulus and matched control cows on 28 dairy farms in New York State ($n = 95$; cases without matched controls were excluded)

	Laboratory normal range[a]					95% Confidence interval	
Analyte (mmol/L)	Lower limit	Upper limit	Cases	Controls	Odds ratio[b]	Lower bound	Upper bound
			Percent Below Normal				
Ca	2.08	2.60	69.5	23.2	8.3	3.4	21.6
P	1.58	2.94	36.8	13.7	3.2	1.5	6.9
Mg	0.75	1.25	26.3	14.7	2.2	0.96	5.3
Na	135	153	24.2	13.7	2.1	0.9	5.0
K	3.9	6.0	15.8	2.1	Undef	2.5	∞
Cl	92	117	20.0	3.2	17.0	2.4	343
HCO_3^-	21	31	26.3	15.8	2.3	0.9	5.6
Anion gap	14	23	2.1	0.0	Undef	0.3	∞
			Percent Above Normal				
HCO_3^-	21	31	6.3	0.0	Undef	1.1	∞
Anion gap	14	23	40.0	16.8	3.4	1.6	7.8

Ca — calcium; P — phosphorus; Mg — magnesium; Na — sodium; K — potassium; Cl — chloride; HCO_3^- — bicarbonate; Undef — Undefined; ∞ — infinity

[a]Clinical Pathology Laboratory, College of Veterinary Medicine, Cornell University

[b]Odds ratio = 1 implies no association between disease and abnormal concentrations; odds ratio > 1 is interpreted as increased odds of abnormal values for cases; odds ratio < 1 suggests decreased odds for cases

[8.3 mg/dL]) compared with 23% of matched control cows with values below normal. The percentages of cases and controls outside of the laboratory reference range are shown in Table 3. Whether the serum chemistry abnormalities preceded or occurred as a result of DA or RTA was not addressed in this study.

Discussion

Although there have been several publications on the clinical chemistry findings of cows with DA after transport to referral hospitals, we did not find previously published studies on the status of cows with DA or abomasal volvulus at the time of on-farm diagnosis. Also, earlier studies did not compare affected cows with unaffected cows from the same herd. Our results show that cows diagnosed with LDA, RDA, or RTA on farms had a significantly lower total serum Ca concentration than unaffected herdmates. This result differs from a report on cases treated for DA in a referral hospital (18), where no association between LDA and serum Ca concentration was found. Control cows in that study were 20 healthy cows from a herd with no recent history of LDA. Our results are more consistent with other earlier studies, where 55% (17) and 35% (16) of cows with LDA were classified as hypocalcemic. A comparison of cows with LDA with control cows exhibiting normal feed intake and without digestive disorders also showed significantly lower serum Ca concentration in a clinic-based study (19). In our study, 67% of cows with LDA and 70% of cows with LDA, RDA, or RTA had total serum Ca concentrations below the lower limit of the laboratory reference range (2.08 mmol/L [8.3 mg/dL]). The difference between serum Ca concentrations for cases and matched controls was not significantly affected by lactation group or days in milk at the time of diagnosis. It is interesting that the results for 1st lactation cows were similar to those of older cows, although the occurrence of clinical hypocalcemia near parturition rarely occurs in first-calf heifers.

In sheep, a linear relationship was found between diffusible serum Ca concentration and the amplitude of rumen contractions (20). The amplitude of abomasal contractions was not depressed until Ca was low enough to produce clinical signs of hypocalcemia and rumen stasis. Hypocalcemia in goats was found to reduce the rate of abomasal evacuation during times of normal acid-base status but had less of an effect during metabolic alkalosis (21). Madison and Troutt (12) observed a threshold effect in 2 cows with induced hypocalcemia. Abomasal motility was not altered until the Ca concentration was below 1.2 mmol/L [4.8 mg/dL]. In contrast to those results, Daniel (13) found a linear relationship of plasma Ca concentration and rates and amplitudes of abomasal contractions in cattle with induced hypocalcemia. There was moderate correlation of frequency and amplitude of abomasal contractions with plasma Ca concentrations ($r = 0.6$ and 0.5, respectively) over a range of 1 to 3 mmol/L [4 to 12 mg/dL]. The relationship plasma Ca relationship with rumen motility was somewhat stronger than its effect on the abomasum. The range of total serum calcium values for the 72 cases in our study with hypocalcemia was from 1.13 to 2.05 mmol/L [4.5 to 8.2 mg/dL]. The effect of hypocalcemia on abomasal motility potentially contributes to the development of DA or RTA. Low Ca concentration and decreased abomasal or ruminal motility at the time of surgical correction of these conditions could also influence recovery. Administration of Ca salts to cows treated for DA and RTA is safe and inexpensive, but the effect of this therapy on outcomes such as milk production, redisplacement, and culling needs to be investigated.

In addition to Ca concentration, P, Mg, K, and Cl concentrations were lower for cows with DA or RTA than for matched control cows. Mean bicarbonate values were not significantly different between cases and controls, but cows with abomasal disorders were more likely to have either high values ($P = 0.04$) or low values ($P = 0.08$) than were matched controls. Anion gap was higher in cases, reflecting decreased Cl and unchanged Na concentrations relative to control cows. These results differ from a previous hospital-based case series where hyperphosphatemia (44%) and hypermagnesemia (39%) were much more common in cows with LDA than in those in our study (16). In another report, low K (63%) and elevated bicarbonate (27%) were more frequent than in our samples from cows with LDA or RTA (17). This could be due to differences between hospital and field cases, but changes in laboratory methods and reference ranges may also account for these discrepant results.

We chose to measure total serum Ca concentration rather than ionized serum Ca concentration because this laboratory measurement is more accessible and affordable in dairy practice. The use of total serum Ca concentration has the disadvantage that it is less closely related to biological effects of Ca than is ionized Ca (22); however, the correlation between ionized and total calcium in cattle has been reported to be moderate to high (0.4 to 0.9) (22–24). Ionized Ca had a consistent relationship with total Ca in most cows with pathologic conditions (22). The correlation between ionized and total Ca decreased with longer times from drawing blood to analysis, but that appeared to be mostly due to changes in ionized Ca concentrations in stored samples rather than to changes in total serum Ca (22).

Other sample factors that may have influenced our results were storage time before serum separation and freezer storage time. For example, some of the high K values appeared to result from relatively long refrigerator storage times before collecting serum. The effect of sample transport and storage on the analysis of associations between blood chemistry abnormalities and DA or RTA were minimized by handling matched case and control samples in the same way, as much as possible.

We found significant differences for serum Ca, P, Mg, K, and Cl concentrations and anion gap between cows with DA or RTA and control cows matched by herd, parity, and stage of lactation. These serum chemistry abnormalities may have preceded the occurrence of DA or RTA or could have resulted from the decreased feed intake and other effects of the abomasal disorders. Of the minerals and electrolytes measured in the study, most of the previous evidence points to an effect of Ca concentration on abomasal motility. Decreased gastrointestinal motility associated with hypocalcemia may play a role in the development of DA or RTA; it also potentially affects recovery after surgical correction of these conditions.

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