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Clinical analysis of animals with right displacement of the abomasum subjected or not to abomasotomy

Análise clínica de animais com deslocamento de abomaso à direita submetidos ou não à abomasotomia

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Abstract: In cases of right displaced abomasum (RDA), there is an interruption in the digestive flow, with a consequent increase in the abomasal content and intense liquid compression, a condition that requires reversal through an abomasotomy. However, few studies have related the performance of this procedure with the clinical outcome of the animals. Therefore, the aim was to compare the clinical findings of RDA animals, attended at the Garanhuns Cattle Clinic-UFRPE, undergoing surgical correction, with (G2, n=46) or without (G1, n=34) an abomasotomy. Among the clinical findings, heart rate values, both before and after the surgical procedure, were higher in animals undergoing abomasotomy, when compared to G1. Furthermore, anorexia and hyperlactatemia were also more present in G2 animals. The survival rate of the animals was 67.39% (31/46) for G2 and 61.76% (21/34) for G1, with no relation observed (p=0.602) between the performance of the abomasotomy and the clinical outcome. In view of the above, it is possible to confirm the clinical and laboratory compromise in animals with RDA and that, despite the more significant anorexia, tachycardia, and hyperlactatemia in G2 animals, abomasotomy was shown to be effective for the treatment of these cases.

Key-words: clinical findings; cattle, surgical procedure; lactate.

Resumo: Nos casos de deslocamento do abomaso à direita (DAD), ocorre uma interrupção no fluxo digestivo com consequente aumento do conteúdo abomasal e intensa compressão líquida, condição que requer reversão por meio da abomasotomia. Entretanto, poucos trabalhos relacionam a realização desse procedimento com o desfecho clínico dos animais. Diante disso, objetivou-se realizar uma comparação dos achados clínicos de animais com DAD, atendidos na Clínica de Bovinos de Garanhuns, Campus da Universidade Federal Rural de Pernambuco, submetidos à correção cirúrgica, com a realização (G2, n=46) ou não (G1, n=34), da abomasotomia. Entre os achados clínicos, os valores de frequência cardíaca, tanto antes como depois do procedimento cirúrgico, foram superiores nos animais submetidos à abomasotomia, quando comparados ao G1. Além disso, a anorexia e a hiperlactatemia também foram mais presentes em animais do G2. O índice de sobrevivência dos animais foi de 67,39% (31/46) para o G2 e de 61,76%

(21/34) para o G1, não sendo observada relação (p=0,602) entre a realização da abomasotomia e o desfecho clínico. Diante do exposto, é possível ratificar o comprometimento clínico e laboratorial nos animais com DAD e que, apesar da anorexia, da taquicardia e da hiperlactatemia mais expressivas nos animais do G2, a abomasotomia mostra-se eficaz para o tratamento desses casos.

Palavras-chave: achados clínicos; bovinos; procedimento cirúrgico; lactato.

1. Introduction

Displaced abomasum (DA) is one of the main diseases that affect the digestive system of dairy cows during the postpartum period, causing significant losses in productivity [1-5]. Although this disorder has a multifactorial etiology, it is believed that, primarily, it involves hypomotility or abomasal atony, with consequent accumulation of gas, which are related to a diet rich in soluble carbohydrates and the production of excessive amounts of gas and of short-chain fatty acids inside the abomasum [6,7].

According to the antimere in which the abomasal condition occurs, the disease can be classified as displacement of the abomasum to the left (LDA) and right displaced abomasum (RDA). The latter presents more unfavorable clinical conditions, as it intensifies the blockage of the digestive flow and predisposes the organ to rotate, a condition called abomasal volvulus (AV) [7-11]. Affected animals may present varying degrees of apathy, dehydration, loss of appetite or anorexia, reduced milk production, colic, abdominal distension, and a metallic "ping" sound in the region where the organ is displaced with the sound of liquid (sloshing) when performing a ballottement test, in addition to alterations in the quantity and physical characteristics of feces [3,7].

With the interruption of the digestive flow, there is an increase in content inside the abomasum, causing liquid compression that can increase circulatory disorders already present, particularly in cases of RDA and, especially, in abomasal volvulus (AV). In these cases, surgical correction using exploratory laparotomy on the right flank followed by gas decompression, through puncture, and liquid, through abomasotomy, should be instituted [12-14]. Although the performance of abomasotomy in cases of RDA with marked with marked intra-abomasal fluid compression is widely disseminated in the literature, studies relating this technique to the patients' clinical outcome are scarce [15,16].

In view of this, the current work aimed to carry out an analysis of cases of RDA, attended in a hospital routine, treated surgically, with or without abomasotomy, considering the clinical and laboratory characteristics and the survival rate.

2. Material and methods

To carry out this study, the clinical records of 80 cattle treated at the Garanhuns Cattle Clinic, Campus of the Federal Rural University of Pernambuco (CBG-UFRPE), diagnosed with displacement of the abomasum to the right (RDA), between 1999 and 2023, were analyzed. The diagnosis was established based on physical examination associated with changes in the concentration of chloride content in rumen fluid (≥ 30mEq/L) [7,12,17].

Group G1 (n=34) was composed of animals with RDA that were not indicated for abomasotomy, while G2 (n=46) comprised animals that underwent this procedure. Data were collected from clinical records regarding the general condition of the animals (rectal temperature, degree of dehydration, respiratory and heart rates) [17], specific examination of the digestive system (appetite, dynamics of the gastrointestinal tract, and changes in feces) [17], and laboratory data, such as blood count, plasma fibrinogen, plasma L-lactate, blood glucose, and β-hydroxybutyrate (BHB).

In addition to the information, data were collected on the occurrence of concomitant diseases, as well as on clinical evolution, post-surgical heart rate, time for appetite and rumen dynamics to return, period of hospitalization, and clinical outcome, considering hospital discharge as a positive outcome and euthanasia or natural death as a negative outcome. The diagnosis of concomitant diseases was established based on clinical examination, exploratory laparotomy through the right flank, and/or necropsy, performed on animals with a negative outcome.

Blood samples were collected by jugular venipuncture, with a 25x8mm needle in tubes with a Vacutainer® system containing EDTA anticoagulant, for hematological analysis, sodium fluoride/EDTA, for glucose determination (Glucose Liquiform®), and L-lactate (Lactato Enzimático®) in a semi-automatic biochemical analyzer (BIO 2000®), and without anticoagulant, to determine the concentration of BHB in a portable dosimeter (Ketovet®). The blood count and determination of plasma protein and plasma fibrinogen were performed according to Harvey [18]. Rumen fluid samples were analyzed according to Dirksen *et al.* [17], and chloride content was measured using a commercial kit (Clorides Liquiform®).

All animals underwent surgical correction of the RDA, which consisted of exploratory laparotomy on the right flank, with the patient in a quadrupedal position (Figures 1A-1F), whether or not they underwent abomasotomy, according to the technique described by Trent, [14]. The criteria for performing abomasotomy were based on the inability of the abomasum to reposition after gas decompression due to excessive fluid accumulation; and the possibility of exteriorization of part of the abomasum through the surgical incision, considering the degree of circulatory impairment.

Figure 1. Clinical-surgical aspects of cows with RDA treated at CBG-UFRPE. A. Right side view of a cow with RDA in a containment chute to perform the surgical procedure; dotted area demonstrates the position of the displaced abomasum. B. Exploratory laparotomy; displaced and distended abomasum, but without changes in the serosa of the organ. C. Right exploratory laparotomy; displaced abomasum, with marked distension and circulatory disorder, evidenced by cyanotic abomasal serosa. D. Exposure of the body of the abomasum through the surgical wound and performance of the abomasotomy for liquid decompression. E. Abomasal contents drained from cow with RDA via abomasotomy. F. Application of suture to portion of pylorus and omentum to perform the abomasal fixation technique. Source: CBG/UFRPE, 2023.

The therapeutic protocol established was based on clinical-surgical and laboratory findings and the particularities of each patient, according to Trent [12] and Barragry [19].

The quantitative variables were subjected to normality (Shapiro-Wilk) and homogeneity (Levene) tests in order to identify their distribution. For those that met these assumptions, the means were analyzed using the Student's T test. Non-parametric and/or heterogeneous data, even after radical or logarithmic transformation, were subjected to the Mann-Whitney U test for median comparisons in their untransformed form. Categorical variables were expressed as frequency and submitted to Pearson's

Chi-square test, in the absence of expected values lower than five in at least one cell of the 2x2 contingency table, or Fisher's exact test, when this condition was not achieved. The binary logistic regression method was also used to calculate the Odds ratio in order to verify the influence of abomasotomy on the patients' clinical outcome. In all analyses, the statistical software IBM® SPSS®, version 25 was used, considering $p<0.05$ [20].

3. Results

In both groups (n=80), the majority of patients were females (98.75%), mixed breeds of Gir and Holstein (63.25%), aged over 24 months (91.25%), raised in a semi-intensive or intensive system (87.50%). The occurrence of RDA was highest in the first postpartum trimester (60.00%), with greater frequency during the region's dry period (between October and March), totaling 53.75% of cases.

In the anamnesis, reduced appetite, decreased milk production, absence of rumination, ruminal bloating, apathy, and the presence of melena were reported. On the property, the average time for clinical evolution, the period between the identification of clinical signs and the search for care, was three days for G2 and four days for G1 (Table 1), with no difference between the groups (p=0.443). Among the clinical findings (Table 1), tachycardia stood out in G2 animals, being significantly higher compared to G1 animals (p=0.049).

Table 1. Measures of central tendency and dispersion of clinical findings of cattle with RDA not submitted (G1; n=34) or submitted (G2; n=46) to abomasotomy, treated at CBG-UFRPE.

Variable		G1	G2	p-value
Onset of clinical signs (days)	Median (Q1-Q3)	4 (3 - 8)	3 (2 - 8)	0.443
Rectal temperature (°C)	Mean ± SD	38.55 ± 0.96	38.73 ± 0.77	0.526
Degree of dehydration	Median (Q1-Q3)	2 (1 - 3)	2 (2 - 3)	0.383
RR (rmpm)	Median (Q1-Q3)	32 (20 - 40)	30 (24 - 40)	0.832
HR (bpm)	Median (Q1-Q3)	80 (64 - 108)	98 (80 - 104)	0.049

Md: median. x: mean. Q1: first quartile. Q3: third quartile. SD: standard deviation. RR: respiratory rate in respiratory movements per minute (bpm). HR: Heart rate, in beats per minute (bpm), on the day the animal was admitted to the hospital (hospital discharge). Variables expressed as mean and standard deviation were subjected to Student's t-test. Variables expressed as median and interquartile range were subjected to the Mann-Whitney U test.

The most prominent clinical findings of the digestive system are described in Table 2. Among them, anorexia stands out, observed mainly in animals from G2 (p=0.041), of which 76.00% (35/46) did not accept the roughage or the concentrate offered.

Table 2. Absolute and relative frequency of clinical variables of the digestive system of cattle with RDA not submitted (G1; n=34) or submitted (G2; n=46) to abomasotomy, treated at CBG-UFRPE.

Variable	G1	G2	p-value	Test
Anorexia	18 (52.94%)	35 (76.09%)	0.041	χ^2
Hypomotility or ruminal atony	23 (67.64%)	35 (76.09%)	0.432	χ^2
Undefined ruminal extracts	23 (67.64%)	32 (69.57%)	0.460	χ^2
Presence of ruminal tympany	15 (44.11%)	24 (52.17%)	0.247	χ^2
Abdominal distension	19 (55.88%)	33 (71.74%)	0.269	χ^2
Increased abdominal tension	22 (67.70%)	28 (60.87%)	0.240	χ^2
Absence of feces	07 (20.58%)	11 (23.91%)	0.539	χ^2
Presence of melena	07 (20.58%)	10 (21.74%)	0.481	χ^2

χ^2: Pearson's Chi-square test.

Among the laboratory findings (Table 3), leukocytosis due to neutrophilia with a regenerative left shift was observed in both groups. Despite this, none of the hematological variables showed differences between the groups.

Table 3. Measure of central tendency and dispersion of laboratory findings of cattle with RDA not submitted (G1; n=34) or submitted (G2; n=46) to abomasotomy, treated at CBG-UFRPE.

Variable		G1	G2	p-value	Reference[21]
Enthrocytes ($x10^6/\mu L$)	Mean ± SD	6.76 ± 1.82	7.15 ± 1.74	0.369	8.0–10.0
Hemoglobin (g/dL)	Mean ± SD	10.71 ± 2.45	11.08 ± 1.96	0.503	8.00 – 15.00
Globular volume (%)	Mean ± SD	32.56 ± 7.44	32.7 ± 7.36	0.935	24.0 – 46.0
MCV (fL)*	Mean ± SD	49.01 ± 4.99	47.28 ± 5.57	0.191	40.0 – 60.0
MCHC (%)**	Mean ± SD	32.91 ± 2.51	32.66 ± 2.26	0.668	30.0 – 36.0
TPP (g/dL)	Median (Q1-Q3)	7.05 (6.00-8.00)	6.80 (6.10-7.50)	0.728	7.0 – 8.5
PF (mg/dL)	Median (Q1-Q3)	600 (500-900)	600 (500-800)	0.684	300 – 700
Total leukocytes (µL)	Mean ± SD	15574.23 ± 8050.47	16016.07 ± 6696.10	0.897	4000 – 12000
Lymphocytes (µL)	Median (Q1-Q3)	5981 (4366-8362)	5742 (4010-7791)	0.531	2500 – 7500
Neutrophils (µL)	Mean ± SD	7359.77 ± 4543.96	8678.15 ± 4628.33	0.348	600 – 4000
Rods (µL)	Median (Q1-Q3)	110.5 (0-324)	192 (0-604)	0.376	0 – 120

x: mean. Md: median. Q1: first quartile. Q3: third quartile. SD: standard deviation. * Mean corpuscular volume. ** Mean corpuscular hemoglobin concentration. TPP: total plasma protein. PF: plasma fibrinogen. Variables expressed as mean and standard deviation were subjected to Student's t-test. Variables expressed as median and interquartile range were subjected to the Mann-Whitney U test.

Regarding blood biochemistry (Table 4), animals in group G2 presented more pronounced hyperlactatemia (p=0.007) compared to animals in group G1. Hyperglycemia was identified in animals in both groups, but with no difference between them (p=0.780). Regarding the chloride content in ruminal fluid, no difference was observed between the groups (p=0.952), with G1 having a median of 43.63 mEq/L (33.56-57.87) and G2 of 47.23 mEq /L (34.58-61.52).

Table 4. Measure of central tendency and dispersion of blood biochemical findings of cattle with RDA not submitted (G1; n=34) or submitted (G2; n=46) to abomasotomy, treated at CBG-UFRPE.

Variable		G1	G2		Reference
Plasma glucose (mg/dL)	n	10	14	0.780	45.0 – 75.0 [22]
	Mean ± SD	103.87 ± 44.67	108.32 ± 29.40		
B-Hydroxybutyrate (mmol/L)	n	14	20	0.180	< 1.10 [23]
	Median (Q1-Q3)	0.59 (0.27-0.80)	0.46 ± (0.29-0.70)		
Plasma L-Lactate (mmol/L)	n	12	23	0.007	0.56 – 2.22 [22]
	Mean ± SD	2.03 ± 1.24	4.28 ± 2.56		

x: mean. Md: median. Q1: first quartile. Q3: third quartile. SD: standard deviation. Variables expressed as mean and standard deviation were subjected to Student's t-test. Variables expressed as median and interquartile range were subjected to the Mann-Whitney U test.

No differences were observed between the groups regarding the frequency of concomitant illnesses (Table 5). In 51.25% (41/80) of the animals, the occurrence of illnesses associated with RDA was observed, highlighting abomasitis with 27.5% (22/80) of cases, and peritonitis with 10.0% (8/80).

Table 5. Absolute (n) and relative (%) frequency of concomitant diseases diagnosed in cattle with RDA not submitted (G1; n=34) or submitted (G2; n=46) to abomasotomy, treated at CBG-UFRPE.

Concomitant illness	G1	G2	p-value	Teste
Abomasitis	08 (23.53%)	14 (30.43%)	0.335	χ^2
Metritis	00 (00.00%)	01 (02.17%)	0.575	Fsh
Peritonitis	06 (17.65%)	02 (04.35%)	0.057	Fsh
Phytobezoar abomasal obstruction	01 (02.94%)	03 (06.52%)	0.417	Fsh
Vagal indigestion	02 (05.88%)	03 (06.52%)	0.642	Fsh

χ^2: Pearson's chi-square test. Fsh: Fisher's exact test.

During exploratory laparotomy, changes in the abomasal serosa were observed in 28.26% (13/46) of the animals in G2 and 14.70% (05/34) in G1 (Table 6). When verifying the occurrence of alterations in the abomasal wall in animals with different clinical outcomes (positive or negative) within the groups, no significant difference was observed (p=0.151). The changes described include edema (27.77%; 05/18), changes in color (66.67%; 12/18; Figure 1C), and necrosis (5.56%; 01/18).

Another finding during exploration was the presence of abomasal volvulus (AV), found in 26.09% (12/46) and 17.64% (06/34) of the animals in G2 and G1, respectively (Table 6). Similar to what was found for changes in the abomasal serosa, there was no difference (p=0.431) between the occurrence of AV in patients with different clinical outcomes in each group.

The drained abomasal content was measured in 86.95% (40/46) of the animals, with an average volume of 26 liters. Of these patients, 35.0% (14/40) had a volume of fluid removed of up to 15 liters, 32.5% (13/40) between 15 and 30 liters, and 32.5% (13/40) greater than 30 liters (Figure 1E). Among the characteristics of the abomasal fluid, RDA brown or black coloration, identified in 72.5% of the animals (29/40), and a foul odor, observed in 65.0% of the cases, stand out (26/40).

Regarding the clinical evolution variables (Table 6), tachycardia was significantly more pronounced after the surgical procedure in G2 (p=0.011), but no difference was observed between the groups for the period of hospitalization, which remained at seven days, as well as the period for the return of appetite (one day for both groups) and ruminal dynamics (two days for G2 and three days for G1).

Table 6. Absolute (n) and relative frequency (%), median and interquartile range of clinical evolution variables of cattle with RDA not submitted (G1; n=34) or submitted (G2; n=46) to abomasotomy, treated at CBG-UFRPE.

Variable		G1	G2	p-value
Abomasal serosa alteration	n (%)	05 (14.70)	13 (28.26)	0.151
Abomasal volvulus	n (%)	6 (17.64)	12 (26.09)	0.286
HR (bpm)	Median (Q1-Q3)	62 (60-84)	80 (68-92)	0.011
Return of appetite (days)	Median (Q1-Q3)	1 (1 - 1)	1 (1 - 2)	0.341
Return of rumen dynamics (days)	Median (Q1-Q3)	3 (1 - 4)	2 (2 - 3)	0.469
Hospitalization period (days)	Median (Q1-Q3)	7 (4 - 9)	7 (4 - 8)	0.604
Positive clinical outcome	n (%)	21 (67.76)	31 (67.39)	0.602

Md: median. Q1: first quartile. Q3: third quartile. HR: heart rate, in beats per minute (bpm), determined one day after the surgical procedure. The categorical variable was subjected to Pearson's chi-square test. Quantitative variables were subjected to the Mann-Whitney U test.

Overall, the survival rate of the animals in the current study was 65.00% (52/80), 67.39% (31/46) for G2 and 61.76% (21/34) for G1 (Table 6). When verifying the relationship between the performance of abomasotomy and the clinical outcome of patients, it was found that the use of this technique did not result in a significant increase (p=0.602) in the chances of a negative outcome (Odds ratio: 1.279; 95% CI: 0.507 - 3.231; p=0.602).

4. Discussion

The majority of cows in the study presented RDA in the first trimester postpartum, in addition to being reared in a semi-intensive or intensive breeding system, conditions in which a high-energy density diet is provided in order to maintain and enhance milk production, which constitutes a risk factor for the occurrence of the disease [5,7,14]. With the decrease in digestive flow, there is accumulation of digesta in the lumen of this organ which, added to the gas present in the contents arising from fermentation in the pre-stomach and that produced in the abomasum, causes intense distension of the organ [7-9,14]. Abomasal distension, associated with increased histamine release, arising from inflammatory processes; the presence of short-chain fatty acids in the abomasal lumen, especially butyric acid; and parasympathetic stimulation of the vagus nerve, increase the volume and acidity of abomasal secretions, producing a positive feedback phenomenon [14,24-26].

Among the clinical and laboratory variables analyzed, only heart rate, anorexia, and plasma concentration of the enzymatic lactate differed between the groups (p<0.05), with the remainder of the variables being discussed in all animals with RDA.

Dehydration was found in 90% (72/80) of the animals and can be attributed to fluid sequestration in the abomasum and the inability for the abomasal contents to progress to the duodenum [27-28]. Supporting this assertion, an increase in the chloride content in the rumen fluid is observed, the main

indicator of reflux of abomasal contents [17], and, consequently, interruption of the digestive flow. These results demonstrate that, although RDA causes water disorders and blockage of the digestive flow, liquid compression did not act to enhance these effects.

The more pronounced tachycardia in animals undergoing liquid decompression, both in the pre-surgical evaluation and after the procedure, reflects the severity of these cases, as also verified by Soares *et al.* [19], who found that heart rate was the only variable that remained a predictor of prognosis in animals with RDA. Similarly, other studies confirmed the applicability of this clinical variable to define the severity in animals with this digestive disorder [8,9,16].

The decrease or absence of appetite in animals with RDA, more evident in G2, and also found in other studies [1,27,30], may be associated with the blockade of digestive flow; pain caused by abomasal distension, and consequent compression of internal organs, and abomasal inflammatory alterations; and metabolic disorders caused by the clinical framework [7,31-33].

Ruminal changes were identified in most animals and included hypomotility or atony, undefined stratifications and ruminal tympany. According to Constable *et al.* [7], mechanoreceptors in the abomasum detect overfilling and reflexively decrease reticuloruminal movements in order to reduce the flow rate of food contents into the abomasum. Furthermore, the contractility of fermentative chambers can be inhibited by changes in blood pH, electrolyte imbalances, dehydration, and hyperglycemia, which are frequent alterations in cases of RDA [1,27,30] and consistent with the results of the current study. Other noteworthy changes in the digestive system were increases in the abdominal perimeter and tension, observed in more than 66% of the animals, which may be related to abomasal distension and ruminal tympany.

The hemodynamic repercussions of the severity of RDA clinical conditions, assessed through plasma L-lactate dosage, were more severe in G2. Hyperlactatemia is mainly caused by tissue hypoxia, since this compound is the product of anaerobic glycolysis, thus constituting a sensitive biomarker of tissue hypoperfusion [34,35]. In a study on the relationship between abomasal perfusion and the intraluminal pressure of the organ in cases of abomasal displacement, Wittek *et al.* [36] found a negative correlation between these two variables, with rapid abomasal decompression being necessary to reduce the potential for ischemia-induced injuries to the abomasal mucosa, such as abomasal ulcers and perforations.

According to the results, liquid compression in cases of RDA played a role in intensifying abomasal ischemia, reflected in L-lactate levels in G2. Other studies have also verified the occurrence of hyperlactatemia in cases of RDA. When comparing the biochemical profile of cattle with LDA and RDA, Coutinho *et al.* [37] and Ribeiro *et al.* [38] found high L-lactate values at the time of diagnosis in cases of RDA, which significantly reduced at the time of hospital discharge. From another perspective, Proios and Grünberg [27] observed that the group of cows with RDA which had a negative outcome presented higher levels of L-lactate when compared to animals with the disease, but with a positive outcome.

Although Boulay *et al.* [39] determined that cows with RDA with L-lactate concentrations between 2.0 and 6.0 mmol/L have a greater chance of a negative clinical outcome, our results do not demonstrate the influences of levels of this metabolite on the survival rate of the patients. Boulay *et al.* [39] also highlighted that L-lactate associated with heart rate, another indicator of cardiovascular system overload [8,9], has greater predictive power for prognosis. However, Soares *et al.* [29] found that this metabolite was not

effective in predicting the prognosis of animals with RDA, as the intensity of hyperlactatemia found in animals with a negative outcome did not differ from that in animals with a positive outcome.

Hyperglycemia, identified in animals from both groups, was also reported in other studies that evaluated cows with RDA [27,37-40]. Some theories can explain the cause of hyperglycemia identified in cattle with this disease, including the increase in serum cortisol levels induced by metabolic stress [27,41] and the impairment of blood circulation in the pancreatic parenchyma, due to changes in the position of the duodenum and omentum due to the abomasal condition, which promotes reduced insulin secretion and a consequent increase in blood glucose levels [40]. As in other studies [37,38,41], the animals under study did not present high levels of BHB, excluding the possibility of an association between RDA and ketosis, an important metabolic disease that affects high production cows in the postpartum period as a consequence of negative energy balance [23,42].

Even with dehydration identified in the studied animals during the physical examination, no alterations were observed in the values of globular volume and total plasma protein in either group. These results are similar to those found by Câmara *et al.* [1] in cows with DA, but they differ from the findings of Braun *et al.* [30] and Proios and Grünberg [27], who found hemoconcentration associated with dehydration in animals with this condition. In turn, plasma fibrinogen, one of the main acute phase proteins measured in ruminants, remained at concentrations considered normal for the species [21], which is consistent with other results in the literature [27,30], since this condition is not primarily inflammatory.

Leukocyte changes, characterized mainly by leukocytosis with neutrophilia and regenerative left shift [21], were also identified by Câmara *et al.* [1] in animals with RDA, who associated them with acute inflammatory processes and the probable influence of concomitant diseases. In the current study, abomasitis was the most frequent concomitant diagnosis, followed by peritonitis. Both diseases, as they are acute inflammatory diseases [7,43], have the capacity to alter leukocyte parameters, being mainly associated with ischemic lesions of the abomasal mucosa and consequent formation of type IV or V ulcers with extravasation of the contents to the abdominal cavity [43-46].

All animals in G2 underwent abomasotomy in a quadrupedal position, which did not increase the occurrence of peritonitis when compared to animals in G1, and maintained satisfactory levels of therapeutic success. From a therapeutic point of view, the use of abomasotomy is mainly indicated for excision of abomasal ulcers, phytobezoar removal, and abomasal decompression [13,14,46-48]. The right paramedian or right paracostal approach, with the patient in lateral or dorsal decubitus, is the most recommended [14]. The main complication of performing this technique on animals in a quadrupedal position is the reduced capacity for exteriorization of the organ and the greater possibility of contamination of the abdominal cavity [14,47]. Corroborating the results found here, there are reports of this procedure with the patient in a quadrupedal position to remove phytobezoars with high success rates [49,50].

Although fluid decompression is necessary in cases of RDA with intense fluid accumulation, the use of abomasotomy is not properly recorded in the literature. Previous studies determined that performing this procedure in cases of RDA was a worsening factor in the prognosis of the animals [11,15,51]. Similarly, Gröhn *et al.* [16] determined that performing an abomasotomy increased the chance of a negative outcome by 4.2 times. These findings were not supported by the results obtained in the current research, since this procedure did not show an association with the unfavorable clinical outcome of patients.

Among the findings during RDA correction surgery, changes in the abomasal serosa and the presence of AV stand out. Previous studies found that alterations in the abomasal wall, resulting from compromised vascular perfusion, were associated with an increased chance of an unfavorable prognosis [11,16,27]. In our study, the occurrence of macroscopic changes in the abomasal serosa did not differ between groups, nor between animals in the same group with different clinical outcomes (positive or negative). Thus, liquid compression in the animals in G2 apparently did not act as an influencing factor on this finding.

Similarly, the occurrence of VA was also not affected by the greater intra-abomasal fluid volume or by the clinical outcome of patients in the same group. Contrasting these results, the presence of abomasal rotation in cows with RDA is recognized as one of the main factors that interfere with the patient's therapeutic success, as it is an emergency condition with severe hemodynamic compromise [8,10,11,15,16,51,52]. The findings reported here are probably related to the immediate clinical-surgical care and adequate trans- and post-surgical therapy.

From the results achieved, it is clear that there is a greater proportion of animals with a volume of drained abomasal fluid of less than 30 liters, a volume used by Smith [11], as a severity factor for animals with RDA. According to this author, this condition can be classified into four degrees of severity, using three aspects as a basis: i) the cause of the abomasal distension (gas or liquid); ii) the possibility of repositioning the abomasum with or without the need for liquid decompression; and iii) the amount of liquid inside the organ. The smaller volumes identified in the patients under analysis may be associated with the high success rate of surgical treatment in G2 animals.

Furthermore, the high survival rate of the animals evidenced in this study may be attributed to the rapid referral of the animals by the producers, associated with the clinical diagnosis and surgical procedure carried out immediately, in addition to the established therapeutic protocol. According to Smith [11], adequate fluid and electrolyte replacement therapy is essential for the success of surgical treatment of RDA, as they limit the metabolic effects of this disease. Due to the constancy and composition of abomasal secretions, cases of impaired digestive flow result in marked changes in the hydro electrolyte balance of affected animals, the severity of which depends on the duration and degree of blockage and the presence of vascular impairment [14].

In relation to the clinical evolution variables analyzed (hospitalization period, return of appetite, and return of ruminal dynamics), animals submitted to abomasotomy did not present longer recovery times when compared to animals with RDA, which were submitted only to gas decompression. These results demonstrate that, when liquid decompression is performed in a timely manner, this pre-existing condition has a limited effect on delaying the recovery of animals. Câmara *et al.* [1] found similar results regarding the clinical evolution of patients with RDA, which was faster compared to animals with LDA.

5. Conclusion

Given the results, it is possible to confirm that abomasal fluid compression in animals with RDA acts as an aggravating factor for clinical and laboratory parameters, demonstrated mainly by anorexia, tachycardia, and hyperlactatemia. Despite this, performing abomasotomy does not increase the risk of a negative clinical outcome and does not prolong the recovery time of cows undergoing surgical treatment of RDA. Therefore, abomasotomy can be considered a safe approach in indicated cases, with no negative impact on the patient's clinical recovery.

Declaration of conflict of interest

The authors declare no conflict of interest.

Declaration of data availability

The dataset supporting the findings of this study is not publicly available.

Author contributions

Conceptualization: Silva TA, Soares GSL, Afonso JAB. Data curation: Silva TA, Soares GSL, Mendonça CL, Coutinho LT, Cajueiro JFP, Silva NAA, Afonso JAB, Souto RJC. Formal analysis: Silva TA. Acquisition of funding: Not applicable. Project administration: Afonso JAB, Souto RJC. Methodology: Silva TA, Afonso JAB. Investigation: Silva TA, Soares GSL. Supervision: Afonso JAB, Souto RJC. Validation: Afonso JAB. Writing (original draft): Silva TA. Writing (review and editing): Silva TA, Mendonça CL, Afonso JAB, Souto RJC.

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