ORIGINAL RESEARCH ARTICLES

Biochemical profile of cattle with left displacement of the abomasum: energy balance, uric acid, electrolyte levels, and metabolic relationships

Perfil bioquímico de bovinos con desplazamiento izquierdo del abomaso: balance energético, ácido úrico, niveles de electrolitos y relaciones metabólicas

Perfil bioquímico de bovinos com deslocamento esquerdo do abomaso: balanço energético, ácido úrico, níveis de electrólitos e relações metabólicas

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Received: May 22, 2025. Accepted: October 12, 2025

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To cite this article

Suvarikli-Alan B, İder M, Altunok V, OK M, Camgöz A. Biochemical profile of cattle with left displacement of the abomasum: energy balance, uric acid, electrolyte levels, and metabolic relationships. Rev Colomb Cienc Pecu *Year, Vol, number, and pages pending.* DOI: https://doi.org/10.17533/udea.rccp.e360929

Abstract

Background: Left displacement of the abomasum (LDA), which affects the production performance of high-yielding cows and is frequently manifested in the early postpartum period, leads to significant changes in the metabolism of cows. **Methods:** This study aimed to investigate the changes in biochemical parameters and the correlations between these parameters in dairy cattle with left displacement of the abomasum. The material of the present study consisted of twenty healthy cows and twenty-eight dairy cows with LDA. The serum was analysed for twenty-five different biochemical parameters. **Results:** The levels of glucose, triglycerides, gamma-glutamyl transferase (GGT), aspartate aminotransferase (AST), haptoglobin, β-hydroxybutyrate, NEFA, and amylase enzyme activity were significantly elevated ($p<0.05$) in cows with left displacement of the abomasum compared to healthy cows. Their levels of uric acid, total protein, albumin, potassium, calcium, chlorine, magnesium, phosphate, cholesterol, and HDL significantly lowered ($p<0.05$). The study's results indicated that NEFA was positively correlated with β-hydroxybutyrate concentrations. HDL was positively correlated with albumin and cholesterol levels. Calcium was positively correlated with albumin, phosphorus, magnesium, and chlorine concentrations. A positive correlation was found between uric acid and NEFA, albumin, phosphorus, magnesium, HDL, and cholesterol concentrations. The results showed that the biochemical parameters of cattle with LDA changed, and the identified correlations were associated with metabolic disorders, including negative energy balance, fatty liver, and ketosis in LDA cases. Furthermore, the correlation between uric acid levels and metabolic markers in cows with LDA supports the link between the disease and energy metabolism and liver dysfunction. **Conclusion:** It was concluded that maintaining postpartum energy balance, electrolyte balance, and calcium homeostasis in dairy cows is crucial for preventing abomasal displacement and for evaluating biochemical parameters accordingly.

Keywords: *biochemical parameters; correlation; dairy cow; left displacement of abomasum; uric acid.*

Resumen

Antecedentes: El desplazamiento izquierdo del abomaso (LDA), que afecta al rendimiento productivo de las vacas de alto rendimiento y se manifiesta con frecuencia en el periodo postparto temprano, provoca cambios significativos en el metabolismo de las vacas. **Métodos:** Este estudio tuvo como objetivo investigar los cambios en los parámetros bioquímicos y las correlaciones entre estos parámetros en vacas lecheras con desplazamiento izquierdo del abomaso. El material del presente estudio consistió en veinte vacas sanas y veintiocho vacas lecheras con LDA. Se analizó el suero para determinar veinticinco parámetros bioquímicos diferentes. **Resultados:** Los niveles de glucosa, triglicéridos, gamma-glutamil transferasa (GGT), aspartato aminotransferasa (AST), haptoglobina, β-hidroxibutirato, NEFA y actividad de la enzima amilasa se elevaron significativamente ($p<0,05$) en las vacas con desplazamiento izquierdo del abomaso en comparación con las vacas sanas. Sus niveles de ácido úrico, proteína total, albúmina, potasio, calcio, cloro, magnesio, fosfato, colesterol y HDL disminuyeron significativamente ($p<0,05$). Los resultados del estudio indicaron que los NEFA estaban positivamente correlacionados con las concentraciones de β-hidroxibutirato. El HDL se correlacionó positivamente con los niveles de albúmina y colesterol. El calcio se correlacionó positivamente con las concentraciones de albúmina, fósforo, magnesio y cloro. Se halló una correlación positiva entre el ácido úrico y las concentraciones de NEFA, albúmina, fósforo, magnesio, HDL y colesterol. Los resultados mostraron que los parámetros bioquímicos del ganado con LDA cambiaban y las correlaciones identificadas se relacionaban con trastornos metabólicos como el balance energético negativo, el hígado graso y la cetosis en los casos de LDA. Además, la correlación del nivel de ácido úrico con marcadores metabólicos en vacas con LDA apoya la relación de la enfermedad con el metabolismo energético y la disfunción hepática. **Conclusión:** Se llegó a la conclusión de que sería crucial mantener el equilibrio energético postparto, el equilibrio electrolítico y la homeostasis del calcio en las vacas lecheras para prevenir el desplazamiento del abomaso y evaluar los parámetros bioquímicos en consecuencia.

Palabras clave: *ácido úrico; correlación; desplazamiento izquierdo del abomaso; parámetros bioquímicos; vaca lechera.*

Resumo

Antecedentes: O deslocamento esquerdo do abomaso (LDA), que afeta o desempenho produtivo das vacas de alta produção e se manifesta frequentemente no período pós-parto precoce, conduz a alterações significativas no metabolismo das vacas. **Métodos:** O objetivo deste estudo foi investigar as alterações nos parâmetros bioquímicos e as correlações entre estes parâmetros em vacas leiteiras com deslocamento esquerdo do abomaso. O material do presente estudo consistiu em vinte vacas saudáveis e vinte e oito vacas leiteiras com LDA. O soro foi analisado para vinte e cinco parâmetros bioquímicos diferentes. **Resultados:** Os níveis de glicose, triglicerídeos, gama-glutamil transferase (GGT), aspartato aminotransferase (AST), haptoglobina, β-hidroxibutirato, NEFA e atividade enzimática da amilase aumentaram significativamente ($p<0,05$) em vacas com deslocamento esquerdo do abomaso em comparação com vacas saudáveis. Os seus níveis de ácido úrico, proteínas totais, albumina, potássio, cálcio, cloro, magnésio, fosfato, colesterol e HDL baixaram significativamente ($p<0,05$). Os resultados do estudo indicaram que o NEFA estava positivamente correlacionado com as concentrações de β-hidroxibutirato. O HDL foi positivamente correlacionado com os níveis de albumina e colesterol. O cálcio estava positivamente correlacionado com as concentrações de albumina, fósforo, magnésio e cloro. Foi encontrada uma correlação positiva entre o ácido úrico e as concentrações de NEFA, albumina, fósforo, magnésio, HDL e colesterol. Os resultados mostraram que os parâmetros bioquímicos dos bovinos com ADL se alteraram e as correlações identificadas estavam relacionadas com distúrbios metabólicos como o balanço energético negativo, o fígado gordo e a cetose nos casos de ADL. Além disso, a correlação do nível de ácido úrico com marcadores metabólicos em vacas com ADL apoia a ligação da doença com o metabolismo energético e a disfunção hepática. **Conclusão:** Concluiu-se que seria crucial manter o equilíbrio energético pós-parto, o equilíbrio eletrolítico e a homeostase do cálcio em vacas leiteiras, a fim de evitar a deslocação do abomaso e avaliar os parâmetros bioquímicos em conformidade.

Palavras-chave: *ácido úrico; correlação; deslocamento esquerdo do abomaso; parâmetros bioquímicos; vaca leiteira.*

Introduction

Abomasal displacement (AD) refers to the displacement of the abdominal viscera to either the right or left side in late pregnancy, resulting from positional changes or abomasal atony caused by various factors (Zadnik et al., 2001; Credille & Fubini, 2022). However, displacements on the left side account for approximately 75-90% of all displacements (Credille & Fubini, 2022). Abomasum displacement, a concern for both livestock welfare and economy, is a condition observed in many dairy cattle breeds (Zerbin et al., 2015). The abomasum is predominantly located to the right of the midline in healthy cows. Depending on the enlargement of the gravid uterus, the length of the abomasum shrinks, and its width enlarges in the last three months of pregnancy. The abomasum returns to its physiological position within fourteen days after parturition (Steiner, 2006). Left displacement of the abomasum (LDA) mainly affects dairy cows during the first month postpartum. Thus, the abomasum expands with fluid and gas and is mechanically displaced from its normal position behind the omasum and between the rumen and the left lateral abdominal wall (Zadnik et al., 2001; Steiner, 2006). This lowers the likelihood of cow survival due to symptoms such as loss of appetite and colic, as well as lower milk yield and subsequent illness (Van Winden & Kuiper, 2003; Zerbin et al., 2015). Furthermore, AD may be correlated with concurrent metabolic and reproductive diseases, and most cases of AD appear around the time of parturition (Zerbin et al., 2015).

The accumulation of gas in the abomasum is crucial in the pathogenesis of AD. Increased gas production and hypomotility of the abomasum are hypothetical causes that underlie this disorder. Gas may accumulate when the motility of the abomasum is insufficient. The vagus nerve plays a dominant role in abomasal motility. Besides the effect of the vagal nerve, high levels of volatile fatty acids, endotoxins, metabolic alkalosis, and low blood calcium levels in the rumen and abomasum have been reported as possible causes of reduced motility (Van Winden & Kuiper, 2003). Prenatal disorders (such as dystocia, twins, metritis, foetal membrane retention, ketosis, or milk fever), nutrition, breed, age, milk yield, genetics, stress, metabolic disorders, neuronal disorders, and some other diseases are risk factors for AD (Steiner, 2006; Doll et al., 2009). In particular, nutritional management during the transition period and the negative energy balance in the postpartum period are known to be the major factors leading to abomasal displacement in dairy cows (Mulligan & Doherty, 2008).

It has been reported that cows with LDA exhibit significantly lower body condition scores and consume less dry matter than healthy cows (Song et al., 2020). It has also been reported that LDA is a metabolic disease that induces symptoms such as anorexia and reduced milk production in dairy cattle (Talukder et al., 2015). For the detection of LDA, a ‘ping’ sound is investigated by percussion and auscultation of the left abdominal wall. Typically, the ‘ping’ sound can be heard just above or just behind the last rib, approximately in the third of the abdomen. On rectal examination of cows with LDA, the displaced abomasum can rarely be felt in the left abdomen. In contrast, the medial displacement of the rumen can be felt more than the former, as it causes a palpable gap between the rumen and the left abdominal wall (Mueller, 2011). It has also been reported that impaired lipid metabolism in LDA cows and associated increases in non-esterified fatty acids (NEFA) and BHBA concentrations (Stengärde et al., 2010; Başoğlu et al., 2014; Ismael et al., 2018; Basoglu et al., 2020; Song et al., 2020; Yong et al., 2021) can be used in the diagnosis of cows with LDA. Additionally, it is also reported that increased concentrations of substances such as stearic acid, oleic acid, palmitic acid, myristic acid, and arachidonic acid can be used for diagnosis (Overton et al., 2017; Guo et al., 2019). Also, related studies have reported that high levels of haptoglobin are observed in animals with displacement (Stengärde et al., 2010; Guzelbektes et al., 2010; Maden et al., 2012).

This study aims to investigate the potential usability and correlation of biochemical parameters that may serve as indicators in the clinical diagnosis of cows with left displacement of the abomasum.

Materials and Methods

Ethical statements

The study was carried out with the ethics committee decision (dated 28/03/2024 and No. 2024/050) of the Experimental and Medical Centre unit of Selçuk University (SÜDAM). Twenty-eight cows diagnosed with LDA in the Large Animal Clinic of the Animal Hospital, Faculty of Veterinary Medicine at Selçuk University were used in this study.

Animals and samplings

The blood of the control animals (twenty healthy Holstein cows giving twenty-five to thirty-two litres of milk) was taken from BİODAP, a purified farm located in the Çumra district of Konya. Routine physical examination (pinging and churning sounds during osculo-percussion), an ultrasonographic examination (Mindray DC-6 Vet, China), and the Liptak test were used to diagnose LDA in dairy cows. The diagnosis of LDA was confirmed during the surgical procedure. Left displacement took place between five and twenty-five days after parturition in cows. Blood samples collected from the vena jugularis were centrifuged at three thousand rpm for fifteen minutes, and serum samples were extracted. The samples were stored at -80°C until they were analysed. Glucose, triglyceride, GGT, AST, alkaline phosphatases (ALP), BUN, UA, creatinine, total protein, albumin, Na, K, Ca, Cl, Mg, P, Fe, haptoglobin, NEFA, β-hydroxybutyrate, amylase, lipase, cholesterol, and HDL levels were analysed from serum samples using commercial kits on an autoanalyser (Architect c8000, USA). Bovine serum amyloid A levels were measured in an ELISA reader (Biotek) using commercial ELISA kits according to the reported procedures.

Statistical analysis

Student's t-test was run in the statistical analysis of the study using the SPSS 25 statistical software (IBM Corp®, 2017, Armonk, NY, USA). Data are presented as mean and standard error. Differences were considered statistically insignificant when the results were $p>0.05$. The Pearson rank test was used to investigate possible correlations between the parameters.

Results

Table I shows the results of biochemical parameters obtained from serum samples for each group. Compared to healthy control cows, the glucose ($p=0.001$), triglyceride ($p=0.004$), GGT ($p=0.002$), AST ($p=0.001$), haptoglobin ($p=0.001$), β-hydroxybutyrate ($p=0.001$), NEFA ($p=0.001$), and amylase ($p=0.002$) levels were observed to elevate in the blood profiles of cows diagnosed with LDA. In contrast, the uric acid ($p=0.006$), total protein ($p=0.003$), albumin ($p=0.008$), potassium ($p=0.001$), calcium ($p=0.001$), chlorine ($p=0.009$), magnesium ($p=0.001$), phosphate ($p=0.001$), cholesterol ($p=0.001$), and HDL ($p=0.001$) were lowered. The ALP ($p=0.096$), BUN ($p=0.734$), creatinine ($p=0.057$), sodium ($p=0.095$), iron ($p=0.683$), serum amyloid A ($p=0.868$), and lipase ($p=0.508$) levels did not change.

Table 1. Changes in serum biochemical parameters in healthy cows and cows with Left Displacement of the Abomasum LDA (mean ± SEM).

Parameters	Control (n = 20)	LDA (n = 28)	p value
Glucose (mg/dL)	51,45±2,68	92,96±7,20	0,001
Triglyceride (mg/dL)	13,00±0,56	16,68±1,08	0,004
GGT (U/L)	25,20±1,22	33,54±2,17	0,002
AST (U/L)	84,85±1,77	147,89±8,87	0,001
ALP (U/L)	41,50±1,77	46,64±2,46	0,096
BUN (mg/dL)	23,30±1,12	23,82±1,04	0,734
Uric acid (mg/dL)	2,98±0,01	2,53±0,12	0,006
Creatinine (mg/dL)	0,1±0,02	0,6±0,11	0,057
Total Protein (g/dL)	7,81±0,13	7,15±0,17	0,003
Albumin (g/dL)	2,97±0,08	2,61±0,1	0,008
Na (mmol/L)	137,00±1,58	132,21±2,31	0,095
K (mmol/L)	4,92±0,1	3,60±0,15	0,001

Parameters	Control (n = 20)	LDA (n = 28)	p value
Ca (mg/dL)	9,46±0,14	7,85±0,23	0,001
CI (mmol/L)	95,55±1,01	90,11±1,71	0,009
Mg (mg/dL)	2,09±0,06	1,70±0,07	0,001
P (mg/dL)	6,55±0,24	4,36±0,28	0,001
Fe (ug/dL)	109,45±4,08	104,86±10,37	0,683
Haptoglobin (mg/dL)	15,93±0,99	28,59±1,73	0,001
NEFA (mmol/L)	0,26±0,05	1,69±0,16	0,001
β-hydroxybutyrate (mmol/L)	0,44±0,03	1,29±0,20	0,001
Serum amyloid A (g/mL)	5,97±0,40	5,88±0,39	0,868
Amylase (U/L)	32,10±1,24	41,32±2,49	0,002
Lipase (U/L)	9,00±0,90	8,11±1	0,508
Cholesterol (mg/dL)	169,30±4,06	104,86±7,37	0,001
HDL (mg/dL)	90,30±3,48	49,18±3,92	0,001

* Differences were considered statistically significant at p-values of < 0,05

Table 2 shows the correlations between biochemical parameters in cattle with left displacement of the abomasum. A positive correlation was found between AST and phosphorus concentration ($p=0.032$) and amylase ($p=0.008$) enzyme activity, while a negative correlation was found between AST and cholesterol ($p=0.002$) concentrations. GGT was positively correlated with albumin ($p=0.014$) and total protein ($p=0.026$) concentrations. A positive correlation was found between glucose and triglyceride ($p=0.001$) concentrations. Uric acid was positively correlated with NEFA ($p=0.012$), albumin ($p=0.011$), phosphorus ($p=0.027$), magnesium ($p=0.041$), HDL ($p=0.017$), and cholesterol ($p=0.041$) concentrations.

A positive correlation was found between total protein and albumin ($p=0.002$), triglyceride ($p=0.001$), magnesium ($p=0.017$), HDL ($p=0.048$), and amylase ($p=0.020$) concentrations. A positive correlation was found between cholesterol and HDL ($p=0.004$) concentrations. A positive correlation was found between amylase and calcium ($p=0.030$) concentrations. Calcium was positively correlated with albumin ($p=0.001$), phosphorus ($p=0.045$), magnesium ($p=0.001$), HDL ($p=0.004$), and chlorine ($p=0.002$) concentrations. A positive correlation was found between chlorine and potassium ($p=0.001$) and HDL ($p=0.027$) concentrations. HDL was positively correlated with albumin ($p=0.001$) and magnesium ($p=0.016$) concentrations. A positive correlation was found between magnesium and albumin ($p=0.001$) and phosphorus ($p=0.004$) concentrations. A positive correlation was found between triglyceride and albumin ($p=0.016$) concentrations. A positive correlation was found between phosphorus and albumin ($p=0.004$) concentrations. NEFA was positively correlated with β-hydroxybutyrate ($p=0.002$) concentrations.

Table 2. Pearson correlation analysis of biochemical parameters in cattle with Left Displacement of the Abomasum LDA.

		AST	GGT	Glucose	Uric acid	Total protein	Cholesterol	Amylase	Calcium	Chlorine	HDL	Potassium	Magnesium	Triglyceride	Phosphorus	Albumin	NEFA
Pearson Correlation	**BHBA**	.311	.064	-.360	.137	.322	.078	.095	.111	.274	.198	.062	.285	-.102	-.086	.212	.555**
Sig. (2-tailed)		.107	.745	.060	.487	.095	.693	.629	.574	.159	.312	.754	.141	.607	.665	.279	.002
Pearson Correlation	**NEFA**	.293	.019	.087	.470*	.224	.150	.215	-.078	-.174	.145	-.097	.348	-.042	.320	.291	
Sig. (2-tailed)		.131	.922	.659	.012	.252	.447	.272	.692	.375	.461	.623	.070	.830	.097	.133	
Pearson Correlation	**Albumin**	.066	.457*	.145	.474*	.568**	.134	.225	.607**	.178	.644**	.069	.715**	.452*	.528**		
Sig. (2-tailed)		.737	.014	.461	.011	.002	.496	.249	.001	.366	.000	.727	.000	.016	.004		
Pearson Correlation	**Phosphorus**	.407*	.009	.187	.417*	.153	-.178	.252	.381*	.109	.178	-.031	.528**	.159			
Sig. (2-tailed)		.032	.964	.341	.027	.438	.364	.195	.045	.581	.366	.876	.004	.419			
Pearson Correlation	**Triglyceride**	-.015	.286	.657**	-.006	.582**	.066	.148	.158	-.092	.091	-.108	.292				
Sig. (2-tailed)		.941	.140	.000	.974	.001	.739	.454	.423	.640	.644	.583	.132				
Pearson Correlation	**Magnesium**	.254	.136	.162	.388*	.449*	-.057	.228	.720**	.307	.451*	.078					
Sig. (2-tailed)		.192	.489	.411	.041	.017	.775	.243	.000	.113	.016	.692					
Pearson Correlation	**Potassium**	-.025	.026	-.213	.166	-.224	.146	-.259	.210	.577**	.210						
Sig. (2-tailed)		.901	.897	.276	.399	.252	.457	.183	.284	.001	.284						

Pearson Correlation	**HDL**	-.139	.185	-.096	.447*	.376*	.524**	.206	.532**	.418*
Sig. (2-tailed)		.482	.347	.626	.017	.048	.004	.292	.004	.027
Pearson Correlation	**Chlorine**	.145	-.110	-.319	.040	-.063	-.067	-.021	.551**	
Sig. (2-tailed)		.462	.576	.098	.840	.751	.734	.916	.002	
Pearson Correlation	**Calcium**	.249	.234	-.056	.198	.361	-.153	.410*		
Sig. (2-tailed)		.202	.230	.778	.313	.059	.435	.030		
Pearson Correlation	**Amylase**	.494**	.007	.183	.183	.437*	-.275			
Sig. (2-tailed)		.008	.972	.350	.351	.020	.157			
Pearson Correlation	**Cholesterol**	-.558**	.292	.065	.389*	.175				
Sig. (2-tailed)		.002	.132	.743	.041	.372				
Pearson Correlation	**Total protein**	.034	.420*	.246	.257					
Sig. (2-tailed)		.866	.026	.208	.187					
Pearson Correlation	**Uric acid**	-.054	.253	.206						
Sig. (2-tailed)		.786	.195	.294						
Pearson Correlation	**Glucose**	-.027	.065							
Sig. (2-tailed)		.892	.744							
Pearson Correlation	**GGT**	-.157								

Pearson Correlation: *Correlated parameters are coloured (*: $p < 0.05$, **: $p < 0.01$).

Discussion

A high NEFA level in serum has been identified as one of the determinants for the occurrence of LDA (Ospina et al., 2010). Furthermore, high NEFA and BHBA levels in serum were associated with the development of LDA (Leblanc et al., 2005; Ospina et al., 2010). Nakagawa and Katoh (1998) reported that both NEFA and BHBA levels were significantly elevated in animals with LDA and ketosis. This study revealed that NEFA and β-hydroxybutyrate concentrations were significantly higher (p=0.001) in cows with left displacement compared to the control group (Table 1). The high NEFA and BHBA levels identified in the cows with displacement corroborated the studies (Stengärde et al., 2010; Başoğlu et al., 2014; Ismael et al., 2018; Basoglu et al., 2020; Song et al., 2020; Yong et al., 2021). The rise in NEFA and β-hydroxybutyrate levels suggested that it may be due to fatty liver due to negative energy balance. Moreover, the positive correlation between NEFA and β-hydroxybutyrate concentrations (p=0.002) suggests that fatty liver and subclinical ketosis may develop in animals with LDA due to negative energy balance.

This study indicated that haptoglobin concentration was significantly higher (p=0.001) in the animals with left displacement compared to the control group. The high haptoglobin levels identified in the animals with displacement are compatible with the studies (Stengärde et al. 2010; Guzelbektes et al., 2010; Maden et al., 2012). The increase in haptoglobin concentration suggested that it may be related to an inflammatory response.

The study revealed that triglyceride concentration was significantly higher (p=0.004) in the animals with left displacement compared to the control group. The high triglyceride levels identified in the animals with displacement are consistent with findings from some studies (Nakagawa & Katoh, 1998; Durgut et al., 2016; Ismail et al., 2019). Başoğlu et al. (2014), Song et al. (2020), and Sevinç et al. (2002) reported that triglyceride levels did not change. On the other hand, Ismael et al. (2018) reported that triglyceride levels dropped in animals with LDA. Furthermore, a study also reported that triglyceride levels were higher in cows with ketosis compared to healthy cows (Simonov & Vlizlo, 2015). Different results in lipid profiles may be attributed to different methodologies, nutrition, and overall health conditions of the cows. When all cases are evaluated, fatty liver and ketosis are commonly diagnosed in cows with LDA after parturition as a consequence of impaired lipid metabolism. It may also be due to the fatty liver accompanying LDA cases in early lactation and stress due to environmental conditions (sensitivity to lipolytic signals due to epinephrine and norepinephrine release) that promote triglyceride accumulation.

The present study indicated that cholesterol concentration was significantly lower ($p=0.001$) in animals with left displacement compared to the control group. The low cholesterol levels found in the animals with displacement are similar to some studies (Sevinç et al., 2002; Guzelbektes et al., 2010; Stengärde et al., 2010; Başoğlu et al., 2014; Ismael et al., 2018; Ismail et al., 2019) conducted in cows with abomasum displacement. Furthermore, Nakagawa and Katoh (1998) reported that cholesterol concentration was low in cows with both LDA and ketosis, but Song et al. (2020) reported no change in cholesterol level. The low cholesterol level may probably be correlated with reduced cholesterol synthesis as a consequence of fatty liver disease.

The present study showed that HDL concentration was significantly lower ($p=0.001$) in animals with left displacement compared to the control group. The lower HDL levels found in animals with displacement are compatible with the studies (Sevinç et al., 2002; Durgut et al., 2016; Ismail et al., 2019) conducted in cows with abomasal displacement. The low HDL levels may probably be correlated with reduced HDL cholesterol synthesis as a consequence of fatty liver. The positive correlation between HDL and cholesterol ($p=0.004$) concentrations may indicate impaired lipid metabolism and fatty liver.

The present study revealed that phosphorus ($p=0.001$) and magnesium ($p=0.001$) concentrations were significantly lower ($p=0.001$) in cows with left displacement of the abomasum compared to healthy cows. The lower phosphorus and magnesium levels identified in animals with displacement are compatible with studies conducted by Basoglu et al. (2020) and Delgado-Lecaroz et al. (2000). However, Song et al. (2020) reported that phosphorus and magnesium levels did not change. A drop in calcium, phosphorus, and magnesium levels in cows with left displacement may be due to less feed intake, loss of appetite, impaired absorption in the intestines, and ongoing excretion from the kidneys. The present study indicated that calcium concentration was significantly lower ($p=0.001$) in animals with left displacement compared to the control group. The low calcium levels identified in animals with displacement are compatible with some studies (Basoglu et al., 2020; Al-Rawashdeh et al., 2017; Ismael et al., 2018; Song et al., 2020). Hypocalcaemia with displacements of the abomasum is often subclinical. The low calcium levels may also be related to reduced absorption of calcium from the intestines due to metabolic alkalosis that occurs in displacements, insufficient calcium intake with feeds, or reduced intestinal transit of calcium intake due to displacement of the abomasum as a complication of fatty liver disease, which often progresses with displacements of the abomasum. The positive correlation between calcium and phosphorus ($p=0.045$), magnesium ($p=0.001$), and chlorine ($p=0.002$) concentrations suggests that the transit of contents to the intestines is disrupted in left displacement.

The study revealed that chlorine concentration was significantly lower (p=0.009) in animals with left displacement compared to the control group. Lowered chlorine levels found in animals with displacement are similar to some studies (Ider et al., 2023; Song et al., 2020; Ismael et al., 2018). Lowered chlorine levels may be due to the prolonged period of discharge of the abomasum, resulting in insufficient absorption of chlorine into the intestine.

This study indicated that potassium concentration was significantly lower (p=0.001) in animals with left displacement compared to the control group. A drop in potassium levels found in these animals is compatible with some studies (Basoglu et al., 2020; Başoğlu et al., 2014; Ismael et al., 2018; Song et al., 2020). Although low potassium levels are normal in animals with high milk yield, it may be due to less feed intake, ongoing urinary excretion, and the intracellular entry of K in the blood to buffer the metabolic alkalosis due to displacement.

It was reported that total protein and albumin levels dropped in cattle with AD, and this drop may have developed following liver damage (Sevinç et al., 2002; Ismael et al., 2018; Basoglu et al., 2020; Song et al., 2020). On the other hand, some studies (Guzelbektes et al., 2010; Maden et al., 2012; Başoğlu et al., 2014; Al-Rawashdeh et al., 2017) reported that albumin and total protein concentrations did not change in animals with AD. The present study revealed that albumin and total protein concentrations were statistically lower (p=0.008) in cows with LDA compared to healthy cows. When the study results were evaluated, abomasum displacement and fatty liver disease were observed, along with variations in total protein and albumin levels, which are known to be low in fatty liver disease, depending on the disease in animals. The positive correlation between GGT and albumin (p=0.014) and total protein (p=0.026) concentrations may indicate the development of fatty liver disease.

BUN and creatinine are considered renal function parameters. As a result of the literature review, no study showing that LDA causes renal dysfunction has been found. The present study indicated that uric acid concentration was significantly (p=0.006) lower in animals with left displacement compared to the control group. The positive correlation between uric acid and NEFA (p=0.012), albumin (p=0.011), HDL (p=0.017), and cholesterol (p=0.041) concentrations may indicate a disruption in purine metabolism related to the impairment of liver function due to fatty liver disease.

The present study indicated that amylase enzyme activity was significantly higher (p=0.002) in animals with left displacement compared to the control group. The high amylase enzyme activity found in animals with displacement is compatible with the previous study (Aly et al., 2016). Ismail et al. (2019) reported that the amylase value of animals with left displacement did not change. The present study suggested that the rise in amylase level may probably be associated with local damage caused by circulatory disturbance in the pylorus and duodenum as a consequence of the development of partial flexion in the left displacement of the abomasum.

Serum GGT and AST enzyme activities have been reported to be useful in the evaluation of liver functions in cattle with abomasal displacement (Sevinç et al., 2002). This study revealed that GGT and AST enzyme activities were significantly higher (p=0.002; p=0.001) in animals with left displacement compared to the control group. The high GGT and AST enzyme activities found in animals with displacement are compatible with the studies (Sevinç et al., 2002; Stengärde et al., 2010; Ismael et al., 2018; Başoğlu et al., 2014; Song et al., 2020). Maden et al. (2012) reported that there was no statistical difference in GGT enzyme activity in animals with LDA compared to the control group, while Guzelbektes et al. (2010) and Al-Rawashdeh et al. (2017) reported that AST enzyme activity did not change. The increase in GGT and AST enzyme activities was thought to be correlated with either fatty liver disease or liver cell damage.

The study indicated that glucose concentration was significantly higher (p=0.001) in animals with left displacement compared to the control group. The high glucose levels found in animals with displacement are compatible with some studies (Ider et al., 2023; Guzelbektes et al., 2010; Başoğlu et al., 2014; Al-Rawashdeh et al., 2017; Al-Rawashdeh et al., 2017). Song et al. (2020) and Sevinç et al. (2002) reported that glucose levels did not change. Ismael et al. (2018) also reported that glucose levels dropped in animals with left displacement. On the other hand, in another study, Sevinç et al. (2001) reported low glucose levels in cows with fatty liver disease. Consequently, a review of the studies suggested that stress increases due to displacement of the abomasum may raise glucose levels, and endogenous cortisol may stimulate glycogenolysis.

This study examined serum concentrations of serum amyloid A (p=0.868), ALP (p=0.96), sodium (p=0.095), creatinine (p=0.057), BUN (p=0.734), lipase (p=0.508), and iron (p=0.683) and reported no statistical difference in animals with left displacement compared to the control group. When the results obtained were analysed, it was concluded that displacement of the abomasum was generally associated with electrolyte imbalance and liver dysfunction after parturition. The present study suggests that high BHBA (the gold standard in the diagnosis of ketosis), GGT, and AST (liver function tests), and the low albumin values in the abomasum displacement group may be due to fatty liver or ketosis. Moreover, the results showed that electrolyte levels other than sodium were lowered. In particular, hypochloraemia and hypokalaemia suggested that metabolic alkalosis may develop. In conclusion, it is critical to maintain energy balance, electrolyte balance, and calcium homeostasis after parturition, especially in dairy cows, to prevent displacement.

Declarations

Funding statement

The Scientific Research Projects (BAP) unit of Selçuk University funded this study (Project number: 24401050).

Conflict of interest

The authors declare no conflict of interest.

Author contributions

BSA: Performed the statistical analysis and wrote the manuscript draft. MI: Collected the data, wrote the manuscript draft. AC: Investigation and Writing - Original Draft. VA and MO: Project administration, Writing - Review & Editing.

Use of Artificial Intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

Data availability

The data sets used in the current study are available from the corresponding author on request.

References

Al-Rawashdeh O, Ismail ZB, Talafha A, Al-Momani A. Changes of hematological and biochemical parameters and levels of pepsinogen, histamine, and prostaglandins in dairy cows affected with left displacement of the abomasum. Pol J Vet Sci. 2017; 20(1): 13-18. https://doi.org/10.1515/pjvs-2017-0002

Aly MA, Saleh NS, Allam TS, Keshta HG. Evaluation of clinical, serum biochemical, and oxidant-antioxidant profiles in dairy cows with left abomasal displacement. Asian J Anim Vet Adv. 2016; 11(4): 242-247. https://doi.org/10.3923/ajava.2016.242.247

Başoğlu A, Başpinar N, Coşkun A. NMR-based metabolomic evaluation in dairy cows with displaced abomasum. Turk J Vet Anim Sci. 2014; 38(3): 325-330. https://doi.org/10.3906/vet-1310-52

Basoglu A, Baspinar N, Tenori L, Licari C, Gulersoy E. Nuclear magnetic resonance (NMR)-based metabolome profile evaluation in dairy cows with and without displaced abomasum. Vet Q. 2020; 40(1): 1-15. https://doi.org/10.1080/01652176.2019.1707907

Credille BC, Fubini S. Case 19.2 - Left Displacement of the Abomasum. In: Comparative veterinary anatomy. Academic Press; 2022. p. 1063-1068. https://doi.org/10.1016/B978-0-323-91015-6.00094-7

Delgado-Lecaroz R, Warnick LD, Guard CL, Smith MC, Barry DA. Cross-sectional study of the association of abomasal displacement or volvulus with serum electrolyte and mineral concentrations in dairy cows. Can Vet J. 2000; 41(4): 301-5. https://pmc.ncbi.nlm.nih.gov/articles/PMC1476151/

Durgut R, Sagkan Öztürk A, Ozturk OH, Guzel M. Evaluation of oxidative stress, antioxidant status, and lipid profile in cattle with displacement of the abomasum. Ankara Univ Vet Fak Derg. 2016; 63(2): 137-141. https://doi.org/10.1501/Vetfak_0000002721

Doll K, Sickinger M, Seeger T. New aspects in the pathogenesis of abomasal displacement. Vet J. 2009; 181(2): 90-96. https://doi.org/10.1016/j.tvjl.2008.01.013

Guo YS, Tao JZ, Xu LH, Wei FH, Hu He SH. Identification of disordered metabolic networks in postpartum dairy cows with left displacement of the abomasum through integrated metabolomics and pathway analyses. J Vet Med Sci. 2020; 82(2): 115-124. https://doi.org/10.1292/jvms.19-0378

Guzelbektes H, Sen I, Ok M, Constable PD, Boydak M, Coskun A. Serum amyloid A and haptoglobin concentrations and liver fat percentage in lactating dairy cows with abomasal displacement. J Vet Intern Med. 2010; 24(1): 213-219. https://doi.org/10.1111/j.1939-1676.2009.0444.x

Ider M, Yildiz R, Naseri A, Gülersoy E, Alkan F, Ok M, Erturk A, Sulu K, Durgut MK. Investigation of gastrointestinal injury-related biomarkers in dairy cattle with displaced abomasum. Vet Med Sci. 2023; 9(6): 2893-2900. https://doi.org/10.1002/vms3.1292

Ismael MM, Elshahawy II, Abdullaziz IA. New Insights on Left Displaced Abomasum in Dairy Cows. Alexandria J Vet Sci. 2018; 56(1): 127-136.

Ismail ZB, Al-Majali AM, Al-Rawashdeh O, Daradka M, Mohaffel M. Alterations of pancreatic functions and lipid profiles in dairy cows with left displacement of the abomasum. Vet Med. 2019; 64(5): 204-208.https://doi.org/10.17221/112/2018-VETMED

LeBlanc SJ, Leslie KE, Duffield TF. Metabolic predictors of displaced abomasum in dairy cattle. J Dairy Sci. 2005; 88(1): 159-170. https://doi.org/10.3168/jds.S0022-0302(05)72674-6

Maden M, Ozturk AS, Bulbul A, Avci GE, Yazar E. Acute-phase proteins, oxidative stress, and enzyme activities of blood serum and peritoneal fluid in cattle with abomasal displacement. J Vet Intern Med. 2012; 26(6): 1470-1475. https://doi.org/10.1111/j.1939-1676.2012.01018.x

Mueller K. Diagnosis, treatment, and control of left displaced abomasum in cattle. In Pract. 2011; 33(9): 470-481. https://doi.org/10.1136/inp.d6079

Mulligan FJ, Doherty ML. Production diseases of the transition cow. Vet J. 2008; 176(1): 3-9. https://doi.org/10.1016/j.tvjl.2007.12.018

Nakagawa H, Katoh N. Reduced activity of lecithin: cholesterol acyltransferase in the serum of cows with ketosis and left displacement of the abomasum. Vet Res Commun. 1998; 22: 517-524. https://doi.org/10.1023/a:1006189603071

Ospina PA, Nydam DV, Stokol T, Overton TR. Association between the proportion of sampled transition cows with increased nonesterified fatty acids and beta-hydroxybutyrate and disease incidence, pregnancy rate, and milk production at the herd level. J Dairy Sci. 2010; 93(8): 3595-3601. https://doi.org/10.3168/jds.2010-3074

Overton TR, McArt JAA, Nydam DV. A 100-Year Review: Metabolic health indicators and management of dairy cattle. J Dairy Sci. 2017; 100(12): 10398-10417. https://doi.org/10.3168/jds.2017-13054

Stengärde L, Holtenius K, Tråvén M, Hultgren J, Niskanen R, Emanuelson U. Blood profiles in dairy cows with displaced abomasum. J Dairy Sci. 2010; 93(10): 4691-4699. https://doi.org/10.3168/jds.2010-3295

Sevinç M, Ok M, Başoğlu A. Liver function in dairy cows with abomasal displacement. Rev Med Vet. 2002; 153(7): 477-480.

Sevinc M, Basoglu A, Birdane F, Boydak M. Liver function in dairy cows with fatty liver. Rev Med Vet 2001; 152(4): 279-300.
Simonov M, Vlizlo V. Some blood markers of the functional state of the liver in dairy cows with clinical ketosis. Bulg J Vet Med. 2015; 18(1): 74-82. https://www.cabidigitallibrary.org/doi/pdf/10.5555/20153099780

Song Y, Loor JJ, Zhao C, Huang D, Du X, Li X, Wang Z, Liu G, Li X. Potential hemo-biological identification markers to the left displaced abomasum in dairy cows. BMC Vet Res. 2020; 16(1): 470. https://doi.org/10.1186/s12917-020-02676-x

Steiner A. Surgical treatment of the left displacement of the abomasum: an update. In: XXIV World Buiatrics Congress; 2006; Nice, France. p. 165-169.

Talukder S, Kerrisk KL, Clark C, Garcia SC, Celi P. Rumination patterns, locomotion activity, and milk yield for a dairy cow diagnosed with a left displaced abomasum. NZ Vet J. 2015; 63(3): 180-181. https://doi.org/10.1080/00480169.2014.973462

Van Winden SC, Kuiper R. Left displacement of the abomasum in dairy cattle: recent developments in epidemiological and etiological aspects. Vet Res. 2003; 34(1): 47-56. https://doi.org/10.1051/vetres:2002060

Yong K, Luo ZZ, Luo Q, Yang QW, Huang YX, Zhao XX, Zhang Y, Cao SZ. Plasma metabolome alteration in dairy cows with left displaced abomasum before and after surgical correction. J Dairy Sci. 2021; 104(7): 8177-8187. https://doi.org/10.3168/jds.2020-19761

Zadnik T, Mesaric M, Reichel P. A review of abomasal displacement-clinical and laboratory experiences at the clinic for ruminants in Ljubljana. Slov Vet Res. 2001; 38(3): 193-208.

Zerbin I, Lehner S, Distl O. Genetics of bovine abomasal displacement. Vet J. 2015; 204(1): 17-22. https://doi.org/10.1016/j.tvjl.2015.02.013