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Research article

MILK YIELD, HEMATOLOGICAL AND ELECTROLYTE PARAMETERS IN PRIMIPAROUS DAIRY COWS AFTER LAPAROTOMIC OMENTOPEXY AND ONE-STEP LAPAROSCOPIC ABOMASOPEXY TREATMENTS OF LEFT DISPLACED ABOMASUM

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This study aimed to evaluate the effects of two different treatment options for the correction of left displaced abomasum (LDA) on milk yield, hematological, electrolyte parameters, lactate and cortisol concentrations in primiparous cows. Twenty four Holstein cows were randomly assigned into three groups: cows treated with one-step laparoscopic abomasopexy (LPS, n=8), cows treated by left paralumbar omentopexy (LPT, n=8) and healthy cows (CON, n=8), matched by parity and days in milk. Blood samples were collected before (D0) and after (D0') surgery, and 1 (D1), 3 (D3), 10 (D3) and 30 (D30) days following surgery. LPS and LPT cows at D0 as well as LPT cows at 30 d following surgery had lower milk yield than CON cows ($P<0.05$), while the service period was higher in LPT than in CON ($P<0.05$). WBC was lower at D0 as well as Hb and Ht at D0 and D0' in CON group than those of LPS and LPT ($P<0.05$). Hyponatremia, hypochloremia and hypokalemia at D0 and D0' were observed in LPS and LPT. In addition, LPT cows had lower Na and Cl at D1 and D3 and lower K at D1 than CON ($P<0.05$). Impaired hydration in LPS and LPT cows was accompanied by higher concentrations of lactate at D0, D0', D1 and D3 ($P<0.01$) and cortisol at D0 and D0' ($P<0.01$) compared with CON group, while LPT had higher cortisol at D0' than LPS ($P<0.05$). These results indicated that LPS has the potential to improve the convalescence period of LDA in primiparous cows.

Keywords: dairy cows, abomasal displacement, one-step laparoscopy, omentopexy

INTRODUCTION

Displacement of the abomasum (DA) is an abnormal positioning of the abomasum within the abdominal cavity, and four topographic patterns of DA are recognized:

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left abomasal displacement (LDA), right abomasal displacement (RDA), anterior DA and abomasal volvulus (AV) [1]. The movement of the abomasum from its normal position to the left side is the dominant form of displacement, which DA mostly occurs in Holstein dairy cows [2,3] within the first 30 days after calving [4]. According to Constable et al. [5], the prevalence of LDA is about 80%, while the other three types of displacement are seen less commonly. Although higher milk production and parity (i.e., higher risk in older cows) are important risk factors for DA, Sexton et al. [6] found higher incidence of DA in younger cows. The main consequences of DA are direct impact on health and milk production, increased risk of culling, metabolic diseases, and/or reproductive failures [4,7]. The average milk loss from LDA due to the reduction in milk production during the convalescence period is estimated to be between 7.5% and 11% using a 305-day milk yield [5]. Thus, it is necessary to improve the postoperative and/or productive outcomes of DA especially under field conditions.

There are numerous risk factors in the etiology of DA in cattle. It is widely accepted that hypotony or atony of the abomasum and gas accumulation associated with stress conditions, nutrition and metabolic disturbances are major causes of DA [8]. The main consequences of DA are water and electrolyte disorders, caused by impaired emptying of the contents from the organ and concurrent poor influx and resorption of water and electrolytes. Therefore, besides changes in the leukogram (i.e., increased number of leukocytes), the most common diagnostic blood findings in cows with DA are hemoconcentration as a result of dehydration as well as electrolyte disturbance in the blood hypochloremia and hypokalemia [9,10]. In addition, L-lactate production, could be increased due to systemic tissue perfusion and local hypoperfusion of the abomasum [11]. L-lactate is typically formed by anaerobic glycolysis and its concentration rises because of dehydration and endotoxemia [12,13]. Moreover, L-lactate can, at least in part, be used to predict productive and/or postoperative outcomes for cows with DA [11,14].

There are numerous techniques for repair of the displaced abomasum in cattle, which are either conservative, or invasive [15]. Compared with open surgical techniques, laparoscopic fixation has several advantages: less trauma, better abdominal visualization, less stressful for the animal and applicability in all field conditions [16]. However, to date, little attention has been paid to the changes in cortisol concentration in response to stress and postoperative pain in LDA treated cows [17]. Wittek et al. [18] reported an improved return to normal milk yield and abomasum motility in cows submitted to two-step laparoscopic abomasopexy comparing with omentopexy via right flank laparotomy. In a study focused on acid-base balance and metabolic profile, one-step laparoscopic abomasopexy showed no advantage in comparison with right paralumbar fossa abomasopexy [19]. However, there is no study comparing the effectiveness of laparoscopic abomasopexy in one step [20,21] and left paralumbar omentopexy in primiparous dairy cows.

We hypothesized that a minimally invasive method for surgical correction of LDA would ameliorate postoperative stress and hypomotility in the immediate postoperative period. The aim of this study was therefore to evaluate the effect of one-step laparoscopic abomasopexy compared with left paralumbar omentopexy on hematological and electrolyte parameters, and concentrations of lactate and cortisol in primiparous dairy cows. An additional objective was to evaluate the effect of these two approaches on milk production in ongoing lactation as well as service period.

MATERIAL AND METHODS

Animals and housing

The present study was conducted on a commercial farm in the central part of Serbia, at latitude 44°49'14" North, longitude 20°27'44" East. This cattle population, with 1300 cows and an average milk production of 8500 L per cow annually, was enrolled in the Serbian official milk recording scheme (Central Database) which means that animals are subjected to the Program of Animal Health Protection Monitoring. Cows included in this study were primiparous Holstein cows. The cows were kept in a tie-stall housing system with individual control of feeding and had free access to water *ad libitum* at all times via automated water bowls. During the experimental period cows were fed diets in the form of total mix ration (TMR) formulated to meet or exceed NRC (2001) requirements. The diet was fed in two equal portions at 6.30 AM and 6.30 PM. The cows were milked twice daily, in the morning at 6 AM and in the evening at 6 PM. Ingredients and chemical composition of the early lactation cow diet are listed in Table 1.

Table 1. Ingredients of the TMR for cows in the first 60 days of lactation

Ingredient	
Corn silage, kg/day of DM	6.8
Alfalfa haylage, kg/day of DM	1.9
Brewers grain (wet) kg/day of DM	1.9
Molasses, kg/day of DM	1.5
Cottonseed meal, kg/day of DM	2.3
Corn grain, kg/day of DM	3.9
Barley, kg/day of DM	0.3
Rye grain, kg/day of DM	0.1
Wheat grain, kg/day of DM	0.2
Sunflower meal (34%CP) , kg/day of DM	3.1
Sodium bicarbonate, kg/day of DM	0.1
Calcium carbonate, kg/day of DM	0.1
NaCl, kg/day of DM	0.1

cont. Table 1

Monocalcium phosphate, kg/day of DM	0.1
Vitamin Mineral Mix, kg/day of DM	0.1
Chemical analysis	
Dry matter (%)	50.13
Ash % of DM	6.04
Fat % of DM	4.90
Cellulose % of DM	20.47
Starch % of DM	12.84
Sugar % of DM	2.69
Protein CP% of DM	17.85
RDP (%)	11.84
RUP (%)	5.96
MP (g/kg)	110.75
NDF (%)	35.07
ADF (%)	20.32
Minerals	
Ca (%)	0.68
P (%)	0.48
Energy	
Metabolic energy (MJ/kg DM)	15.0
pH	4.63

DM-dry matter; MP-metabolizable protein; RDP-rumen degradable proteins; RUP-rumen undegradable proteins; NDF-neutral detergent fiber; ADF-acid detergent fiber

A total of 24 primiparous Holstein cows were included in the study. All cows that showed loss of appetite and decreased milk yield in the early postpartum period were examined clinically by simultaneous auscultation and percussion and ballotment of the left thoracic-abdominal wall. Information on participating cows was collected by farm veterinarians during clinical visits. The cows for which a diagnosis of LDA was suspected based on the presence of a typical left-sided tympanic resonance (i.e. ping) were recruited in this study. The cows were enrolled in the study if diagnosis of LDA was confirmed by exploratory laparotomy or endoscopic examination and excluded from this study if another diagnosis was revealed during surgery. Sixteen primiparous cows with LDA were housed in a separated facility, and were randomly divided into two groups according to the abomasum repositioning method: one group treated by laparoscopic abomasopexy (LPS, n=8) in one step according to the method described by Barizani [20] and Christiansen [21], and the other group treated by classical laparotomy (LPT, n=8) over the left paralumbal fossa. Laparoscopic treatment was performed in standing position by using a Dr. Fritz Endoscope (Dr. Fritz, GmbH, Tuttlingen-Möhringen, Germany), while left side laparotomy was performed with concurrent ventral omentopexia. Eight clinically healthy primiparous cows, matched by days in milk, were randomly selected for the control group (CON, n=8). On the seventh day after correction of the LDA and/or when the drug withholding time had expired, treated animals were returned to the production group.

Blood samples and analyses of hematological and electrolyte indices, lactate and cortisol

Blood samples were taken from each cow from *V. caudalis mediana* 30 minutes before treatment (D0) and 15 minutes after repositioning (D0'), 1 (D1), 3 (D3), 10 (D10) and 30 (D30) days after treatments. Blood samples from the CON group were taken at equivalent time points. Venous blood samples for hematological analysis were collected into tubes with K2EDTA anticoagulant (BD Vacutainer, Plymouth, UK) at D0, D0', D10 and D30 time points. In addition, blood samples for the determination of electrolytes and lactate levels were taken in vacutainers with lithium heparin as an anticoagulant (BD Vacutainer, Plymouth, UK). Samples for cortisol determination were taken in gel-coated blood tubes (BD Vacutainer, Plymouth, UK), allowed to clot spontaneously (approximately 20 minutes) on ice, and were subsequently centrifuged at 2000 g for 15 min. The serum was decanted and frozen at - 20 °C until analyzed.

Hematological parameters including total white blood cell (WBC), red blood cell (RBC) and platelet (PLT) counts, hemoglobin (Hb) concentration, hematocrit (Hct) value were determined using an automated hematology analyzer (Phoenix NCC-30 Vet, Neomedica, Serbia).

Analysis of electrolytes sodium (Na^+), potassium (K^+) and chloride (Cl^-), lactate was carried out in the Department for Ruminants and Swine Diseases (University of Belgrade, Serbia) laboratory using the respective tests (No. 20317002) from Nova Biomedical Corporation (Waltham, USA). The concentrations of electrolytes and lactate were determined in heparinized whole blood samples automatically by gas ion analyzer State Profile Prime + Vet (Nova Biomedical Corporation, Waltham, USA). Blood cortisol concentration was determined on an automated immunoassay analyzer (AIA-360, Tosoh Bioscience, Inc., South San Francisco, USA) using original commercial tests from the same producer.

Milk yield and the service period were recorded from all animals included in the study. Data for milk production was monitored on a monthly basis during ongoing lactation (305-days milk production). In addition, milk production at days 30 and 60 relative to treatments was recorded. Data for length of service period was taken from the farm database. The study was approved by the Ethical Committee of the Faculty of Veterinary Medicine, University of Belgrade, in accordance with the National Regulations on Animal Welfare (No. of the document: 26/2020).

Statistical analyses

All data were analyzed using STATISTICA v.8. (StatSoft, Inc., Tulsa, OK, USA) commercial software. The normality of data distributions was tested using the Shapiro-Wilk test. All data were normally distributed (P>0.05). Data are presented as mean ± SE (standard error). The between-groups effect of the two LDA treatments was tested using a repeated measure ANOVA test. When "F" for treatment, time, or interaction showed statistical significance (P < 0.05), differences between mean values were evaluated using a Student t-test. Treatment differences at P<0.05 are considered to be significant.

RESULTS

The prevalence of the displacement of abomasum on a commercial farm in this study was 8.44%, while the occurrence rate of LDA was 81.2%. In addition, 17.1% of the occurrences were primiparous cows and 82.9% of the total number of diagnosed cases were cows with more than two lactations. Both groups of primiparous cows, treated with laparoscopy (LPS) or laparotomy (LPT) methods, were older than cows in the CON group, and a significant difference in age was found between the CON and LPS groups (P<0.05).

Table 2 and Figure 1 summarize the key statistical measures used to compare milk yield between the studied groups of cows. Milk yield was significantly lower before surgery in LPS and LPT as well as at 30 d following surgery in LPT compared to CON (P<0.05, respectively) (Figure 1). Differences in milk yield between the studied groups of cows were not significant at d 60 after treatments or with respect to their 305-day milk production. Service period was significantly higher (P<0.05) in LPT than in the CON group (Table 3).

Table 2. Descriptive statistics for the data on monthly test-day milk yield (L) of healthy and LDA cows

		Months									
Groups	**Statistic**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Control (CON, n=8)	Mean	19.60	26.60	30.80	31.11	30.75	30.25	26.43	23.57	20.50	18.33
	SE	0.52	2.24	1.82	1.99	1.98	1.85	1.97	1.66	1.36	1.72
	Minimum	18	23	15	25	25	24	24	20	18	10
	Maximum	21	40	43	41	40	41	30	28	26	26
Laparoscopy (LPS, n=8)	Mean	14.29	20.86	28.29	30.57	30.29	30.57	26.43	23.14	20.71	18.71
	SE	1.83	3.66	3.87	3.42	1.81	1.61	2.07	1.99	2.13	1.64
	Minimum	8	10	15	19	26	25	21	19	16	11
	Maximum	21	34	40	43	41	36	28	26	24	22
Laparotomy (LPT, n=8)	Mean	15.57	17.29	26.29	28.43	27.14	27	21.43	18.29	15	13.43
	SE	2.05	2.82	2.42	2.06	2.80	2.40	1.62	1.73	1.91	1.60
	Minimum	7	9	19	19	22	19	11	10	8	7
	Maximum	22	32	30	36	32	34	29	28	25	25

CON-control group; LPS-laparoscopy group; LPT-laparotomy group

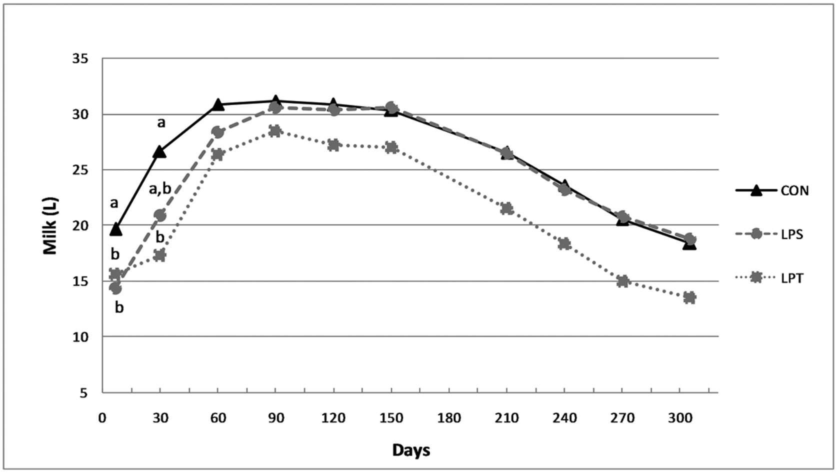

Figure 1. Last square means of monthly milk production (L/d) for control, LPS and LPT cows

Table 3. Mean ± SE and range (minimum and maximum) of the values for general characteristics and production of healthy and LDA cows

Parameters	Control (CON)	Laparoscopy (LPS)	Laparotomy (LPT)
Age, years	2.08 ± 0.03[a] (2.0-2.3)	2.24 ± 0.07[b] (2.0-2.6)	2.16 ± 0.05[ab] (2.0-2.4)
Treatment, days	15.10 ± 2.23[a] (7-29)	17.30 ± 3.85[a] (2-34)	15.10 ± 3.46[a] (5-29)
Milk 30 DIM, L	27.50 ± 1.38[a] (22-35)	23.71 ± 1.82[ab] (16-29)	22.29 ± 1.81[b] (17-30)
Milk 60 DIM, L	30.70 ± 2.28[a] (15-40)	29.43± 2.10[a] (19-36)	26.43 ± 2.22[a] (19-35)
305-day milk yield, L	7960± 327[a] (6800-8800)	7728± 360[a] (6120-9020)	7154± 550[a] (5450-9120)
Service period, days	120.86 ± 10.58[a] (61-139)	157.67 ± 29.02[a] (55-260)	178.83 ± 26.38[b] (106-279)

Milk 30 DIM-day in milk after treatment; Milk 60 DIM-day in milk after treatment
CON-control group; LPS-laparoscopy group; LPT-laparotomy group; LDA-left displacement of abomasum
a,b - Different lower case letters indicate significant differences between groups in rows ($P<0.05$)

WBC count was significantly higher before surgical correction (D0) in LPS and LPT groups than in the CON group ($P<0.05$). After surgery, WBC values did not differ significantly between groups. For RBC and PLT counts, no significant differences were noted between groups across all time points. Concentrations of Hb and Ht value were significantly lower in the CON group ($P<0.05$) than those of LPS and LPT groups at time points D0 and D0'. After that, Hb and Ht values did not differ significantly between groups (Table 4).

Table 4. Mean values ± SE of hematological parameters of healthy and LDA cows before and after treatment

Parameters	Days after treatment LDA	Control (CON)	Laparoscopy (LPS)	Laparotomy (LPT)
WBC ($x10^9$/L)	0	6.43 ± 0.55[a]	10.24 ± 1.61[b]	9.89 ± 1.75[b]
	0'	6.51 ± 0.57[a]	8.93 ± 1.22[a]	8.56 ± 1.14[a]
	10	7.49 ± 0.77[a]	7.60 ± 0.54[a]	7.26 ± 0.75[a]
	30	9.06 ± 1.01[a]	6.49 ± 0.93[a]	6.11 ± 0.94[a]
RBC ($x10^{12}$/L)	0	5.35 ± 0.14[a]	6.30 ± 0.48[a]	6.00 ± 0.43[a]
	0'	5.29 ± 0.15[a]	5.95 ± 0.33[a]	5.80 ± 0.39[a]
	10	5.02 ± 0.09[a]	5.38 ± 0.23[a]	5.33 ± 0.24[a]
	30	4.76 ± 0.17 [a]	4.90 ± 0.19 [a]	5.02 ± 0.28 [a]
Hb (g/dL)	0	8.87 ± 0.20[a]	11.39 ± 0.87[b]	10.36 ± 0.50[b]
	0'	8.81 ± 0.19[a]	10.83 ± 0.57[b]	10.11 ± 0.42[b]
	10	8.63 ± 0.17[a]	9.39 ± 0.33[a]	9.21 ± 0.36[a]
	30	8.44 ± 0.18 [a]	8.50 ± 0.25 [a]	8.49 ± 0.39 [a]
Ht (%)	0	21.00 ± 0.50[a]	27.47 ± 1.98[b]	24.81 ± 1.17[b]
	0'	20.92 ± 0.48[a]	25.99 ± 1.34[b]	24.31 ± 1.16[b]
	10	20.07 ± 0.36[a]	23.10± 1.49[a]	22.03 ± 0.95[a]
	30	19.06 ± 0.45 [a]	20.49 ± 0.83 [a]	19.91 ± 0.87 [a]
PLT (10^9/L)	0	159.29 ± 10.21[a]	185.43 ± 30.92[a]	197.71 ± 23.31[a]
	0'	159.85 ± 10.15[a]	193.00 ± 26.58[a]	239.29 ± 53.00[a]
	10	152.71 ± 8.60[a]	175.43 ± 19.33[a]	206.14± 33.07[a]
	30	158.14 ± 11.74[a]	161.43 ± 23.96 [a]	183.71 ± 4.53 [a]

CON-control group; LPS-laparoscopy group; LPT-laparotomy group; LDA-left displacement of abomasum
a,b - Different lower case letters indicate significant differences between groups in rows (P<0.05)

Electrolyte concentrations are presented in Table 5. Na, K and Cl concentrations were significantly lower in LPS and LPT groups compared with CON (P<0.05 for both) at time points D0 and D0'. In addition, concentrations of Na and Cl at D1 and D3 and K at D1 time points were significantly lower in LPT than those of CON (P<0.05). After that, Na, K and Cl concentrations did not differ significantly between the three groups of cows. Except at time point D10, osmolarities were significantly lower (P<0.05) at all time points (D0, D0', D1, D3 and D30) in LPT than in the CON group.

Before surgery (D0), LPS and LPT cows had significantly higher lactate concentrations than those of CON (both P<0.01). Postoperative concentrations of lactate at D0', D1 and D3 time points were significantly higher in LPT (all P<0.01) and LPS (P<0.01, P<0.01 and P<0.05, respectively) groups compared with the CON. After that, lactate concentrations did not differ significantly between groups (Figure 2).

Table 5. Mean values ± SE of ion parameters of healthy and cows with LDA before and after treatment

Parameters	Days after treatment LDA	Control (CON)	Laparoscopy (LPS)	Laparotomy (LPT)
Na^+ (mmol/L)	0	142.90 ± 4.76[a]	127.90 ± 2.97[b]	128.61 ± 2.04[b]
	0'	142.80 ± 4.74[a]	129.27 ± 2.18[b]	125.73 ± 2.09[b]
	1	142.76 ± 3.24[a]	134.23 ± 3.03[ab]	131.20 ± 4.03[b]
	3	140.16 ± 5.20[a]	133.63 ± 1.82[ab]	132.67 ± 1.13[b]
	10	132.73 ± 1.53[a]	133.34 ± 2.03[a]	132.17 ± 0.99[a]
	30	138.06 ± 1.98[a]	135.03 ± 1.99[a]	131.27 ± 2.76[a]
K^+ (mmol/L)	0	5.02 ± 0.21[a]	4.14 ± 0.14[b]	4.11 ± 0.05[b]
	0'	5.00 ± 0.20[a]	4.01 ± 0.15[b]	3.99 ± 0.13[b]
	1	5.11 ± 0.19[a]	5.10 ± 0.35[ab]	4.59 ± 0.05[b]
	3	4.92 ± 0.17[a]	5.06 ± 0.35[a]	4.63 ± 0.14[a]
	10	4.87 ± 0.10[a]	4.92 ± 0.23[a]	4.72 ± 0.13[a]
	30	4.86 ± 0.16[a]	4.82 ± 0.07[a]	4.71 ± 0.11[a]
Cl^- (mmol/L)	0	109.66 ± 3.72[a]	96.43 ± 1.18 [b]	96.17 ± 2.53 [b]
	0'	109.37 ± 3.74[a]	95.64 ± 1.69[b]	93.97 ± 1.68[b]
	1	107.51 ± 2.23[a]	103.16 ± 2.71[ab]	100.19 ± 2.32[b]
	3	106.84 ± 1.71[a]	103.20 ± 1.39[ab]	100.07 ± 1.54[b]
	10	102.34 ± 0.66[a]	102.70 ± 1.34[a]	102.46 ± 1.89[a]
	30	103.29 ± 0.89[a]	102.94 ± 1.20[a]	100.30 ± 1.90[a]
Osmolarity (mOsmol/kg)	0	288.71 ± 11.22[a]	254.57 ± 5.49[b]	255.57 ± 4.16[b]
	0'	288.30 ± 11.32[a]	257.71 ± 4.65[b]	251.86 ± 4.27[b]
	1	285.43 ± 7.49[a]	266.14 ± 5.68[ab]	259.43 ± 5.20[b]
	3	281.29 ± 7.18[a]	268.71 ± 3.69[ab]	261.14 ± 3.49[b]
	10	264.71 ± 2.78[a]	265.14 ± 2.77[a]	263.71 ± 3.31[a]
	30	277.71 ± 3.35[a]	267.29 ± 3.87[ab]	261.29 ± 3.82[b]

CON-control group; LPS-laparoscopy group; LPT-laparotomy group; LDA-left displacement of abomasum
a,b - Different lower case letters indicate significant differences between groups in rows ($P<0.05$)

Cortisol concentrations were significantly higher in LPS and LPT groups compared with the CON group before (both $P<0.01$) and shortly after treatments (both $P<0.01$). In addition, LPT cows had significantly higher concentrations of cortisol compared with LPS cows at time point D0’ ($P<0.05$). Differences in cortisol concentrations between groups were not significant at days 1, 3, 10 and 30 relative to surgical treatments (Figure 3).

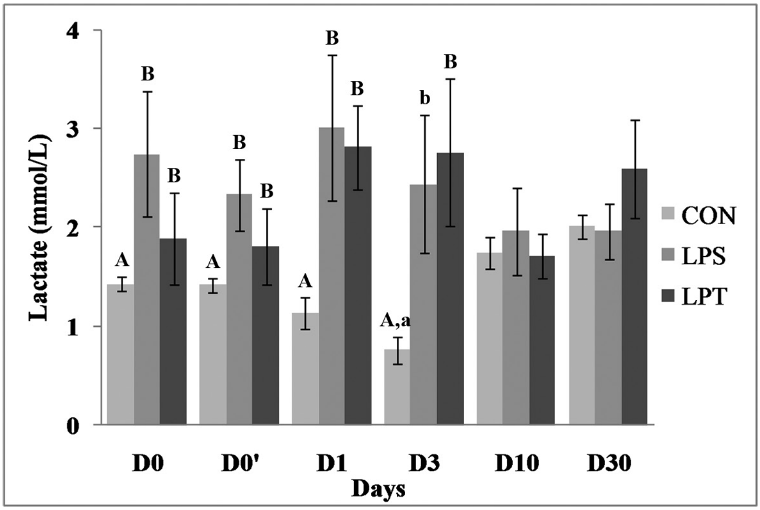

Figure 2. Lactate concentrations of healthy and LDA cows before and after treatment
CON-control group; LPS-laparoscopy group; LPT-laparotomy group
a,b - Different lower case letters indicate significant differences between groups (P<0.05)
A,B - Different upper case letters indicate significant differences between groups (P<0.01)

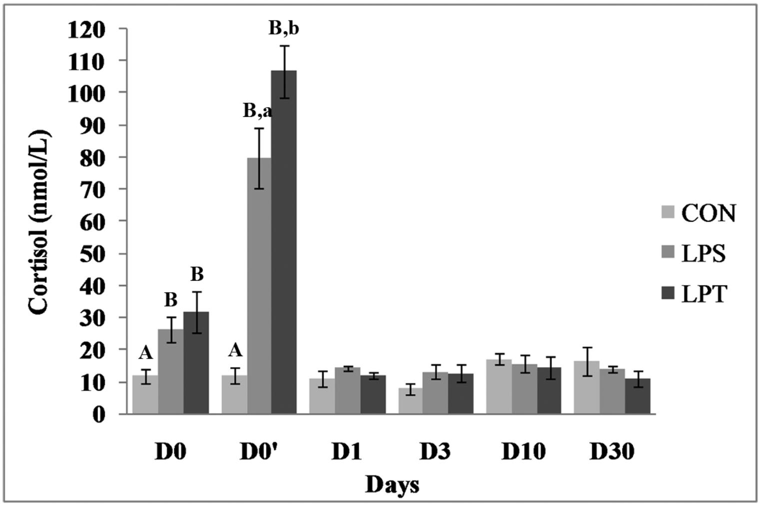

Figure 3. Cortisol concentration of the healthy and LDA cows before and after treatment
CON-control group; LPS-laparoscopy group; LPT-laparotomy group
a,b - Different lower case letters indicate significant differences between groups (P<0.05)
A,B - Different upper case letters indicate significant differences between groups (P<0.01)

DISCUSSION

This is the first research report comparing the one-step laparoscopic abomasopexy and left paralumbar fossa laparotomy treatments for LDA of dairy cows under farm settings in Serbia. Because of a shortage of veterinarians with experience of laparoscopic LDA surgery, many cows with LDA are treated via left paralumbar fossa laparotomy or conservatively. The strengths of this study lie within the chosen of both negative controls (i.e., healthy cows) and cows with LDA treated via left paralumbar fossa laparotomy in assessing the efficacy of the one-step laparoscopic abomasopexy. This study demonstrated for the first time beneficial roles of laparoscopy in one-step on the immediate postoperative stress in primiparous dairy cows. In addition, results showed potentials of one-step laparoscopy in improving milk production and electrolyte responses in primiparous cows treated for LDA. Our results could have implications in choosing the appropriate methods of LDA treatment for minimizing milk losses.

The prevalence of DA (8.44%) and LDA (81.2%) available in the farm database used in the current study were in agreement with findings reported elsewhere [22,23]. In addition, the occurrence rate of LDA in primiparous cows (17.1%) concur with the findings of previous studies, indicating the increased risk of developing DA with higher parity [24,25]. Primiparous cows with abomasal displacement were recorded within a period from 2 to 34 days after parturition, which was similar to those reported by Sexton et al. (2007) [6]. Although the exact cause is unknown, numerous risk factors for LDA such as, feeding, breed, age, milk yield, genetics, stress, metabolic and other diseases have been implicated [2]. However, the lower occurrence rate of LDA in primiparous cows could in part be explained by their lower milk production [26].

Cows treated for LDA generally produce less milk than healthy animals, especially in the first 4 months of lactation [26,27]. There is a lack of information in the available literature comparing the one-step laparoscopic abomasopexy and omentopexy via laparotomy in the left paralumbar fossa on the production and reproduction parameters in primiparous dairy cows. From our results, LPS and LPT cows already had lower milk yield before surgery and at 30 d relative to treatment of LDA in comparison with control cows, although this difference was only apparent in LPT cows at day 30 relative to treatment. The decreasing effect of LDA on the milk yield before treatment was also found by Van Winden and Kuiper [8] and Melendez et al. [27] who explain it by reduced feed intake prior to LDA. Although milk production in surgically treated cows did not differ from controls at day 60 relative to treatment or with respect to their 305-day milk production, LPS cows reached the production level of their matched controls in the third month of lactation and subsequently showed similar production level for the rest of the lactation. These results are in agreement with the findings of Bartlett et al. [28], who found a similar trend of differences in lactation curve for milk yield between the roll-and-toggle procedure for treatment of LDA and healthy cows. This suggests that laparoscopic treatment of LDA may have a beneficial effect on milk production compared with laparotomic correction. However, besides the milk yield, improvements in service period were observed in response to the less invasive LPS method compared with the LPT cows. On the other hand, reduced reproductive efficiency in cows with LDA is in accordance with the study of

Kang et al. [29] who explain it by severe negative energy balance in the postpartum period. The longer service period might be associated with higher age in LPS and LPT cows at the time LDA was diagnosed. Namely, the older heifers likely calved with higher body condition that can negatively affect energy status and conception [2,30].

In the present study, hematology parameters were within the normal range for early lactating cows [5]. However, changes in hematology parameters were detected in the short period of time before treatment and shortly after treatment of LDA, though all of these parameters returned to the physiological range within ten days after surgical correction. Higher hematocrit and hemoglobin concentrations in LDA cows was also found by Zadnik [9], Perotta et al. [16] and Rohn et al. [31]. This could be attributed to dehydration and/or hemoconcentration due to insufficient abomasal emptying and decreased water intake [31]. Moreover, these pathological events help explain the higher Hb levels before treatment and in the immediate postoperative period in LPT and LPS cows. Although in this study higher WBC was detected in cows with LDA before treatment, these values were within the reference range [5]. These findings are in contrast to previously reported findings where leukocytosis with neutrophilia occurred in cows with LDA [9] rather than leukopenia and neutropenia [32]. This discrepancy between the studies could in part be explained by the difference in health status of cows. Furthermore, our observations of lower potassium, sodium and chlorine levels before treatment in cows with LDA are consistent with dehydration and impaired passages of ingest to the small intestine in these cows [33]. In addition, we found a decreasing effect of LDA on electrolyte concentrations in the cows treated for LDA, though recovery to physiological values differed between LPS and LPT groups. In our study, the lower postoperative concentrations of sodium and chlorine on days 1 and 3 as well as potassium on day 1 relative to treatment were found only when comparing CON and LPT groups. This is consistent with an earlier study that found differences in electrolyte concentrations between cows with LDA subjected to one-step laparoscopic abomasopexy versus abomasopexy via the right paralumbar fossa [19]. However, electrolytes in the LPS group had already returned to physiological values in the first day after treatment, a finding also supported by the results of blood osmolarity, suggesting faster reestablishment of gastrointestinal flow in these cows. Our findings are similar to those of Wittek et al. [18], who found more rapid normalization of abomasum motility after laparoscopy treatment. On the other hand, lower concentrations of potassium in cows treated for LDA could be the reason for a longer service period in LPT and LPS cows in this study. Therefore, the 58 days longer, on average, service period in LPT than in the CON group could, at least in part, be the consequence of the slower return of potassium to physiological levels in these cows after treatment. It is known that potassium has an important role in muscle contraction and reduced concentrations of this ion lead to reduced myometrium contractility. Reduced motility of the myometrium and delayed cleaning consequently provokes endometritis, which prolongs the service period in cows [34].

Another fact that emerges from the results of our study is that higher serum lactate levels in animals with LDA before treatment in comparison to healthy animals appears to suggest an abomasal ischemia as a cause [13,38]. We measured lactate and cortisol concentrations after two differing surgical treatments of LDA in primiparous cows. Our findings are interesting because there is no previous information comparing the effects of one-step laparoscopic abomasopexy and left laparotomic omentopexy with regard to lactate and cortisol levels. Higher lactate production is generally found in animal species suffering from digestive disorders, such as in dogs with gastric dilatation and volvulus [35], horses with colic [36] and cows with right displacement of the abomasum and abomasal volvulus [13]. It has been suggested that the lactate concentration can be used as a biomarker in the diagnosis of subclinical acidosis and ketosis [37] as well as a predictor of productive and postoperative outcomes in dairy cows [11,14]. According to Boulay et al. [11], the normal concentration of L-lactate should be ≤ 2.0 mmol/L, and this value is interpreted as a good indicator of a positive outcome. Values between 2.0 and 6.0 mmol/L can be interpreted as the ''gray zone'', while a concentration ≥ 6.0 mmol/L has a very poor prognosis. However, the lactate concentration in the LPS group returned below the value of 2.0 mmol/L on day 30 following surgical correction, while in the LPT group it stayed in the ''gray zone'' during the same period. This finding can, at least in part, be explained by differences in surgical treatment related tissue damage, and further support advantages of laparoscopic surgery. There is also an indication that lactate might be related to stress as interactions between cortisol and lactate concentrations in early lactating cows have been reported [39]. Namely, enhanced serum lactate in cows may result from cortisol-induced vasoconstriction of peripheral blood vessels due to pure tissue perfusion [40]. On the other hand, cortisol may cause a reduction in lactate levels through the use of lactates as gluconeogenic substrates and/or when the beta adrenergic receptors are involved in cortisol-induced hyperglycemia [41]. It is known that stress response depends on the intensity of the stressful stimulus, and some authors found that laparoscopy was less stressful for animals based on indicators of peritoneal inflammation [42]. In the present study, we assessed stress differences between two treatment approaches of LDA through measurements of cortisol concentrations, as cortisol is also known as a stress marker of the endocrine system in cattle [43]. Our study results showed that LPS treatment leads to lower cortisol levels in primiparous cows shortly after surgery compared with LPT, indicating that the LPS procedure of LDA correction is less stressful for animals. Given that both treatments provoked only acute stress in animals with concomitant no difference of serum lactate after treatments between LPS and LPT cows, it is likely that higher lactate concentrations in treated cows did not derive from stress-related differences in generation of lactate. Nevertheless, more research is needed to confirm and further explain the role of lactate in cattle, particularly as some authors have suggested a protective role of lactate against oxidative stress also seen in cows with LDA [25,44].

CONCLUSION

It can be concluded that the use of one-step laparoscopy has the potential to shorten the convalescence period after LDA in primiparous Holstein cows. Therefore, laparoscopy in one step is important not only to ameliorate postoperative stress and hypomotility but also improving milk production. Further research into the implications of such surgery approach to reproductive efficiency will be needed as the carryover effects can persist into the next lactation.

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Authors' contributions

SA, SN, and IV conducted the field experiment and processed blood samples for analysis hematology, electrolyte, lactate, and cortisol. RP, SA, DK, and JB analyzed the results and wrote the manuscript draft. All authors read and approved the final manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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PROIZVODNJA MLEKA, SASTAV KRVI I ELEKTROLITA KOD PRIMIPARIH KRAVA SA DISLOKACIJOM SIRIŠTA NA LEVO NAKON TRETMANA METODOM OMENTOPEKSIJE I LAPAROSKOPSKE ABOMAZOPEKSIJE U JEDNOM KORAKU

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Cilj rada bio je da se uporede dve različite metode tretmana dislokacije sirišta na levo (LDA), kao i da se ispita njihov efekat na proizvodnju mleka, sastav krvi i elektrolita, koncentraciju laktata i kortizola kod primiparih visokomlečnih krava. Dvadeset četiri primipare krave holštajn rase, uparene po paritetu teljenja i danima u laktaciji, raspoređene su u tri grupe: krave tretirane laparoskopskom abomazopeksijom u jednom koraku (LPS, n=8), krave tretirane laparotomijom preko leve gladne jame metodom omentopeksije (LPT, n=8) i kontrolna grupa zdravih krava (CON, n=8). Uzorci krvi uzimani su pre (D0) i posle (D0') operacije i 1 (D1), 3 (D3), 10 (D3) i 30 (D30) dana nakon operacije. Krave iz LPS i LPT grupe su u D0, kao i LPT grupa u D30 nakon operacije imale nižu mlečnost u odnosu na krave CON grupe (P<0,05), dok je servis period bio veći kod LPT grupe u odnosu na CON grupu (P<0,05). WBC je bio niži u D0, kao i Hb i Ht u D0 i D0' u CON grupi u odnosu na LPS i LPT grupu (P<0,05). Hiponatrijemija, hipohloremija i hipokalemija ustanovljene su u D0 i D0' kod krava LPS i LPT grupe. Pored toga, LPT grupa imala je niže vrednosti Na i Cl u D1 i D3 i niže vrednosti K u D1, poređenjem sa CON grupom (P<0,05). Ustanovljeno je da su LPS i LPT grupe krava imale višu koncentraciju laktata u D0, D0', D1 i D3 (P<0,01) i kortizola u D0 i D0' (P<0,01) u odnosu na CON grupu, dok je LPT grupa imala više vrednosti kortizola u D0' u odnosu na LPS grupu (P<0,05). Ovi rezultati su pokazali da primena metode LPS ima potencijal da ubrza period oporavka nakon tretmana LDA kod pimiparih krava.